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Vol. 53 • Issue

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A ROYAL EVENING

WITH

DR. ZAHI HAWASS

THE WORLD'S MOST FAMOUS ARCHAEOLOGIST

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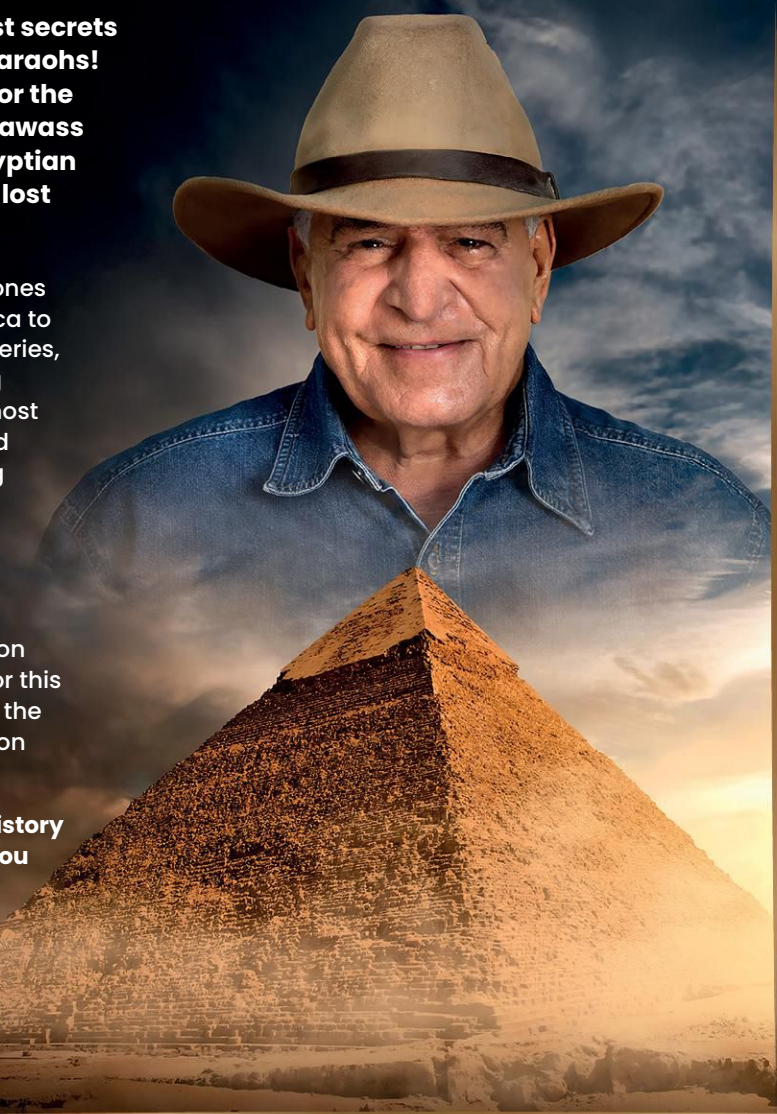
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Dave's Universe
The inside scoop from the editor.

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Questions and answers



"Is Pluto a Planet?"
NASA/JHUAPL/SWRI

With eight planets orbiting the Sun, a few hundred billion stars in the Milky Way, and 100 billion or more galaxies in the universe, there's a lot to think about in this interest of ours. And never before has the pace of discovery been so great. We are learning more about the universe and how it works every week, at an unprecedented level. Yet countless questions remain about this big cosmos.

Every month we publish a department that has long been a reader favorite, Ask Astro, which is expertly edited and guided along by our Senior Editor Alison Klesman. This month we add to that. Associate Editor Michael E. Bakich has penned a story you'll most likely enjoy: "40 Cosmic Questions Answered" details a few of the biggest areas we often think about when gazing up at a star-filled sky.

"What does $E=mc^2$ mean?"
"How close is the nearest galaxy to Earth?"
"What is the *New General Catalogue*?"
"Is the Moon moving away from Earth?"

The questions span all facets of what keeps you adhered to the fascinating hobby of astronomy. They cover the solar system, the galaxy, the distant universe, and questions and answers relating to cosmology — the origin and fate of the universe. They also address ideas related to how we practice the hobby of astronomy. Mr. Bakich, a veteran sky enthusiast for decades, is poised to understand astronomy enthusiasts, and to anticipate and respond to the ideas, thoughts, and questions that percolate through all of our minds.

I hope that your experience in amateur astronomy is a good one, and that you are enjoying *Astronomy* magazine. We have plans to bring you some special materials in the coming months, and, well, what can we do in the meantime?

Start by answering your questions. Have fun out there under the stars.

Yours truly,

David J. Eicher
Editor



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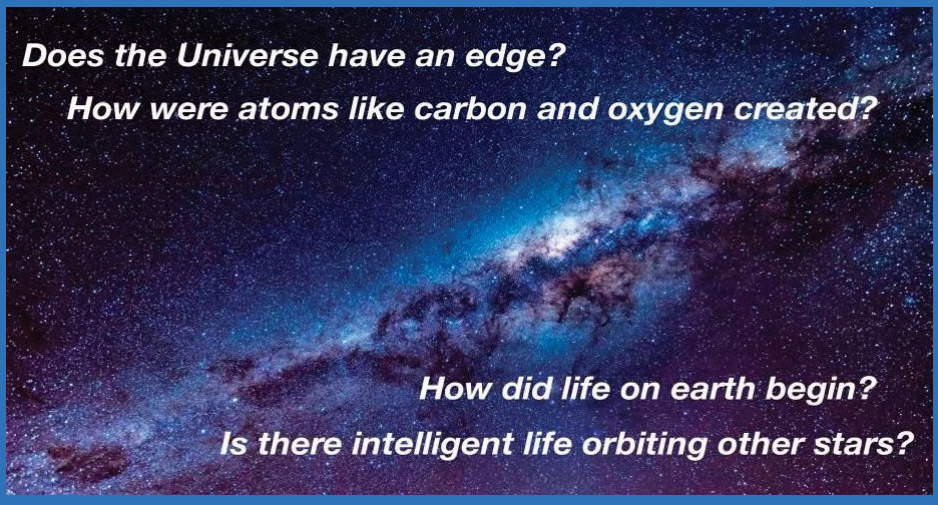
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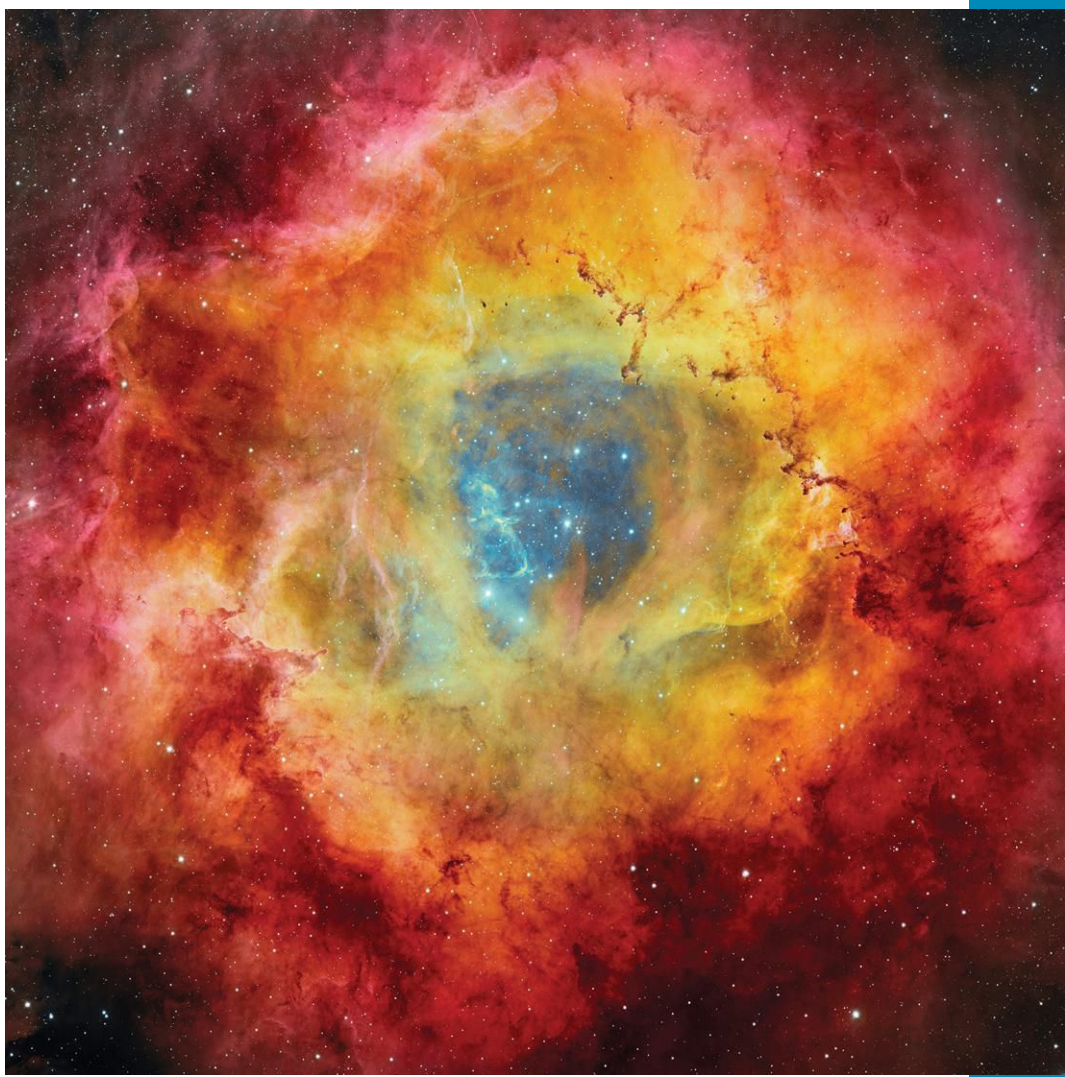
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SNAPSHOT

A BLOOMING NEBULA

The Dark Energy Camera takes a portrait of this famous deep-sky object.

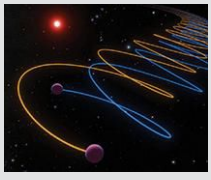


Close-up photos of flowers may be clichéd — but when the flower in question is the Rosette Nebula, and the camera is the powerful 570-megapixel Dark Energy Camera (DECam), mounted to the Victor M. Blanco 4-meter Telescope in Chile, who can complain? This image of the Rosette and the open cluster NGC 2244 shrouded within its petals was released Oct. 1. The object lies 5,000 light-years away in Monoceros. At upper right, thorny clouds of cold dense gas line the cavity where winds from young stars are blowing outward. In stellar nurseries, as this cold gas is swept away, the dense cores behind often form trunklike features or pillars; in the Rosette, however, the local magnetic field alters the flow of the winds, causing the resulting tendrils to appear twisted and clawlike.
— MARK ZASTROW

CTIO/NOIRLAB/DOE/NSF/AURA; IMAGE PROCESSING: T.A. RECTOR (UNIVERSITY OF ALASKA ANCHORAGE/NSF NOIRLAB), D. DE MARTIN & M. ZAMANI (NSF NOIRLAB). BOTTOM FROM LEFT: K. MILLER, R. HURT (CALTECH/IPAC); ESA – S. CORVAJA; RODNEY POMMIER

»

HOT BYTES



SURPRISE TWINS
Gliese 229B became the first-ever confirmed brown dwarf — a failed star, not quite massive enough to fuse hydrogen into helium — in 1995. But two papers published Oct. 16 show that this object is in fact a binary system, with two brown dwarfs orbiting each other.



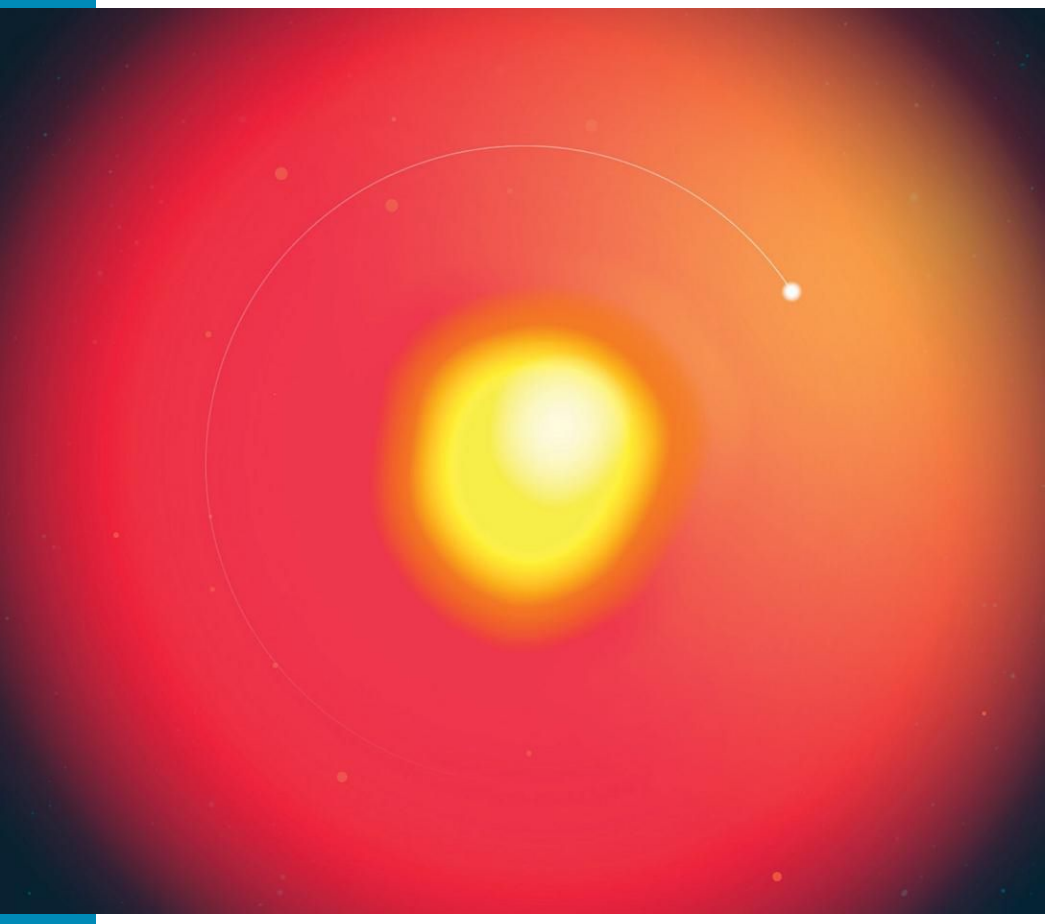
HERA TAKES FLIGHT
The European Space Agency's Hera mission launched Oct. 7, heading for Dimorphos, the asteroid moonlet whose orbit NASA altered with its Double Asteroid Redirection Test in 2022. The craft will survey the impact's aftermath.



KEEPER OF THE DARK
American astronomer Beverly Lynds, renowned for her 1962 catalog of 1,802 dark nebulae (featuring the designation LDN), passed away Oct. 5 at the age of 95.

BETELGEUSE MAY HAVE A BETELBUDDY

Some variations of the bright naked-eye star Betelgeuse may be caused by an unseen companion.



HIDDEN COMPANION. The red supergiant star Betelgeuse (center) may have a companion star closely orbiting it, as depicted in this illustration. LUCY READING-IKKANDA/SIMONS FOUNDATION

The bright red supergiant star Betelgeuse has long been a familiar sight for stargazers, winking with a ruddy glow from the shoulder of Orion the Hunter. But it also holds allure for professional astronomers thanks to its scientific peculiarities, ranging from pulsations to mysterious dimming events.

Now, astronomers think they may have found the key to Betelgeuse's strange behavior: Two independent studies posted to the *arXiv* preprint server argue that Betelgeuse is actually part of a binary system, with a previously unknown companion star.

This proposed second star is much smaller than Betelgeuse and so far remains unseen; both teams inferred its presence based on how its gravity gently tugs Betelgeuse back and forth in the sky. But if astronomers can confirm the star with observations, it could explain Betelgeuse's longest pulsation, which has baffled astronomers for decades.

PLAYING THE LONG GAME

Betelgeuse's strange behavior comes in the form of variations in brightness. The star pulsates in brightness not with a single rhythm, but to a range of overlapping beats with periods as short as a few hundred days and as long as thousands of days.

Most researchers think that its 416-day cycle is the star's so-called fundamental mode (its lowest-frequency intrinsic oscillation) and the shorter modes are overtones (higher frequencies of the first). But some researchers believe that Betelgeuse's longest cycle, lasting 2,170 days, is the star's fundamental mode. If true, it would indicate that Betelgeuse is twice as large as generally thought — and set to go supernova at any moment.

Previously, scientists have hypothesized that this long secondary period (or LSP) could be explained by a low-mass companion star or large planet transiting or occulting Betelgeuse and blocking some of its light. But detecting such a companion next to an extremely bright, variable star is a steep challenge.

The key for both studies was comparing Betelgeuse's LSP to astrometric and radial velocity data, revealing that the star moves ever so slightly on the sky, as if pulled by an unseen companion.

A team led by Jared Goldberg from the Center for Computational Astrophysics at the Flatiron Institute in New York analyzed astrometric observations — measurements of Betelgeuse's position — from the European Space Agency's Gaia space telescope and found that Betelgeuse's movements can only be explained by a low-mass companion star orbiting every 2,170 days. They submitted their paper to the *arXiv* preprint server Aug. 17; it has been accepted for publication in *The Astrophysical Journal*.

A second group, led by Morgan

MacLeod from the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, used astrometric data as well as a century's worth of radial velocity data derived from spectra with red and blue shifts; these indicate how quickly Betelgeuse moves toward and away from us. They submitted their discovery to the *arXiv* just a month later, on Sept. 17.

Both teams agree that the invisible companion can't be much more than the mass of the Sun, which makes it a mere one-twentieth the mass of Betelgeuse. And it circles Betelgeuse at a distance just shy of Saturn's average orbital distance — the rough equivalent of one Betelgeuse-width away from the surface of the star itself.

DIMMER SWITCH

Betelgeuse provided one more twist to the story. "Prior to our work," Goldberg tells *Astronomy*, "a leading theory for LSP behavior was a companion with a dusty tail occulting the star. But from the radial velocity, it has to be the other way around — dust blocks the star when the companion isn't in view!"

MacLeod's team came to the same conclusion. Instead of the companion blocking light from Betelgeuse and causing a dip in brightness, the companion is apparently clearing out dust like a snowplow, causing Betelgeuse's light to shine a bit more brightly during eclipse.

This could tie in neatly with the dust puff explanation for the Great Dimming in 2020, Goldberg's team proposes in their paper. The dimming happened near LSP minimum, when the theorized companion would have been behind Betelgeuse. That would put its L3 Lagrange point, an orbital quirk of gravitational stability, directly between Betelgeuse and earthly viewers, possibly funneling the dust cloud along our line of sight and obscuring the star's light.

The next obvious step is attempting to observe the companion, but Goldberg says that "may not even be possible with current instruments." As of this writing, Goldberg and his colleagues had obtained approval for observations around Dec. 6, 2024, when they predict the companion will be at its widest separation from Betelgeuse from our point of view. Although this will enhance their chances, Goldberg still calls the observation "a bit of a long shot," because Betelgeuse is 100,000 times brighter than its companion.

But Betelgeuse has always been full of surprises. Perhaps this time, its odds-defying nature will work in our favor.

– KOREY HAYNES

A well-worn wheel



NASA/JPL-CALTECH/MSSS

After more than 20 miles (32 kilometers) traveled over 12 years of trekking across Gale Crater on Mars, the right middle wheel of NASA's Curiosity rover has seen better days, as this image taken Sept. 22, 2024, shows. The rover snapped the photo with its Mars Hand Lens Imager (or MAHLI), a camera on the end of its robotic arm, as it conducted one of its periodic inspections of its wheels. But despite appearances, the wheel is actually holding up well, says NASA, and isn't holding the rover back. In fact, Curiosity's continued mobility is what has given NASA confidence that Curiosity's twin, Perseverance, will be alive and kicking if it is called upon to deliver its rocks to a sample return vehicle at the end of the decade. (See "NASA rethinks Mars Sample Return" on page 14.) – M.Z.

QUICK TAKES

BARNARD'S EXOPLANET

Barnard's Star — the closest single star to Earth — hosts an exoplanet about half the mass of Earth with surface temperatures of about 257 F (125 C), says an Oct. 1 paper in *Astronomy & Astrophysics*.

MARS' HABITABLE ZONE

Ice on Mars could be hospitable to life, finds a study. At depths between several inches and 10 feet (3 m) — depending on how dusty it is — ice could shield microbes from ultraviolet radiation while allowing enough light through for photosynthesis.

ORIGIN STORY

As many as 70 percent of all known meteorites originate from just three parent main-belt asteroids. These parents broke up in collisions 5.8 million, 7.5 million, and roughly 40 million years ago, telescope data and computer simulations show.

SOLAR MAX

The current solar cycle — the 25th since sunspot records began — has peaked, scientists from NASA, NOAA, and the International Solar Cycle Prediction Panel announced Oct. 15.

THE LONG GOODBYE

Voyager 2's plasma science instrument has been turned off as the craft's plutonium power source fades. Four science instruments remain operational on the probe, which launched in 1977.

THE GOOD METEORITE

An impact 3.26 billion years ago from a meteorite more than 50 times the mass of that which wiped out the dinosaurs may have helped life emerge on Earth. It may have released phosphorus into the environment and dredged up iron-rich water from ocean depths, upon which microbes could feed. – M.Z.

SpaceX makes historic booster catch



MOTOR SKILLS. As Super Heavy approached the tower, the metal "chopstick" arms swung in toward the booster, allowing it come to rest atop the arms on cantilevered flaps protruding from its fuselage. SPACEX

ON OCT. 13, Starship and the Super Heavy booster lifted off around 8:25 A.M. EST from SpaceX's Starbase launch pad in Boca Chica, Texas, on the rocket's fifth suborbital test flight. But rather than splash down in the Gulf of Mexico, as it did on the previous flight, the 233-foot-tall (71 meters) Super Heavy booster flew back to the pad, where it slowed to a hover and was caught in midair by a pair of metal "chopstick" arms atop the launch tower.

It was the first time such a maneuver had been successfully completed — or attempted — and represents a key milestone in the development of Starship, the largest and most powerful rocket system ever flown.

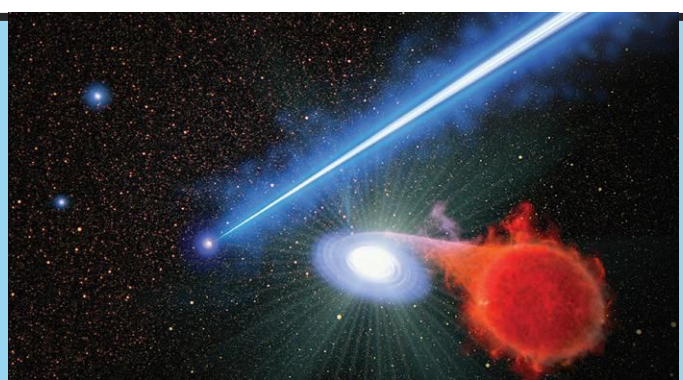
The ability to return Super Heavy and Starship directly to the launch pad is intended to speed the turnaround process — a crucial element of fulfilling the company's vision of sending humans to the Moon, Mars, and beyond. For instance, SpaceX is working under a $4 billion NASA contract to develop a human landing system (HLS) variant of Starship that will ferry astronauts from lunar orbit to the Moon's surface. A single lunar trip may require upwards of a dozen Starship launches to fill a planned refueling depot located in low Earth orbit.

Starship, meanwhile, completed its own objectives, coasting about halfway around the planet before reentering the atmosphere, flipping itself around, and making a controlled splashdown in the Indian Ocean. For this flight, SpaceX upgraded Starship's thermal protection systems; this appeared to prevent the loss of flaps and other hardware that were damaged during reentry on the previous test flight.

The next step for SpaceX is to validate orbital flight and demonstrate on-orbit propellant transfer between two Starships, which the firm plans to attempt as early as March 2025.

—JACK DALEO

BLACK HOLE JET SPARKS COSMIC FIREWORKS



FIRE WHEN READY. Like a science-fiction weapon, the plasma jet of M87 appears to be causing the outer layers of stars to explode. NASA, ESA, J. OLMSTED (STSCI)

CLASSICAL NOVAE occur when a white dwarf in a binary system pulls matter off its red giant companion. Eventually, a tipping point is hit and the white dwarf's outer layer undergoes a runaway nuclear reaction, blasting away in a bright flash of light.

These eruptions normally happen sporadically. But when the Hubble Space Telescope recently turned its gaze toward the galaxy M87, astronomers spotted double the expected amount of novae along the massive 3,000-light-year-long jet blasting out of the supermassive black hole at the galaxy's center.

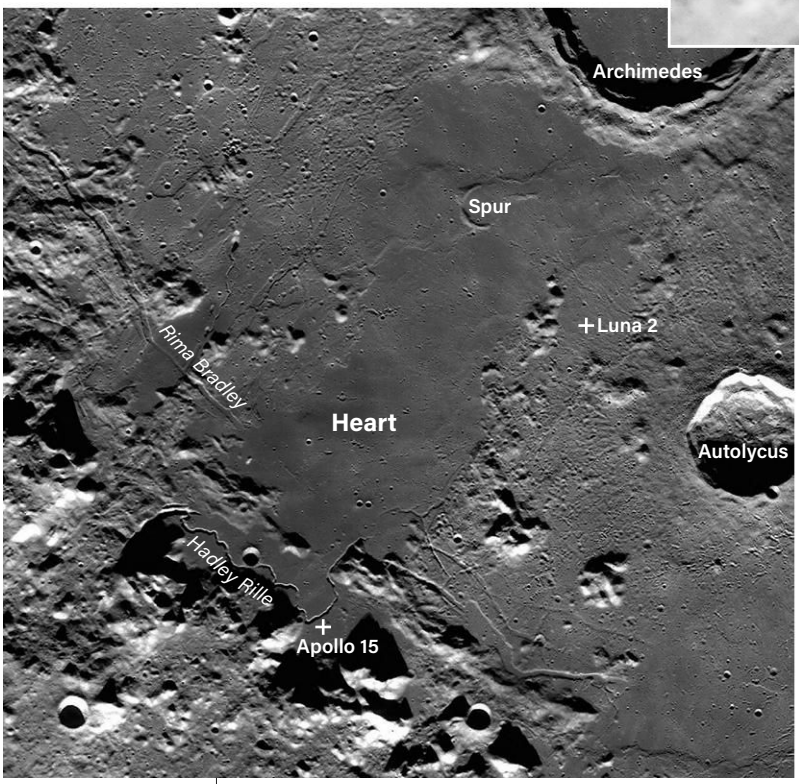
Astronomers have noted hints of strange novae behavior near M87's center since Hubble began operations. The new study, which has been accepted for publication in *The Astrophysical Journal*, presents observations of 135 classical novae clustered around M87's plasma jet. This is twice as many as what's considered normal for the rest of the galaxy.

"We are witnessing an intriguing but puzzling phenomenon," said Chiara Circosta, a European Space Agency research fellow who was not involved in the study, in a press release.

It's not clear how the jet is causing the novae, but astronomers speculate that either the jet's matter or radiation is helping to push hydrogen fuel onto the white dwarfs and causing them to erupt more frequently. But scientists will have to wait for future Hubble observations, as it's the only telescope — for now — that can resolve these novae against the bright background of the galaxy. —DANIELA MATA

The Moon's beaded heart

Be dazzled by a different kind of string of pearls this Valentine's Day.



A few lunar features around the Palus Putredinis region are labeled in this Lunar Reconnaissance Orbiter image. NASA



BY STEPHEN JAMES O'MEARA
Stephen is a globe-trotting observer who is always looking for the next great celestial event.

As Valentine's Day approaches, I thought I'd share with you a lunar phenomenon created by the interplay of light and shadow on the Moon. It's a delightful pattern of lunar peaks and ridges that, when illuminated in the correct way, looks like a string of beads forming the shape of a heart. Catch it under the right light this month, and you can share the view with the ones you love.

The Heart lies near the Apollo 15 landing site, roughly between crater Archimedes and the Hadley Rille (or Rima Hadley) — so close that astronauts David Scott and James Irwin could have waved to it. From our earthly perspective, one can imagine the Heart as a monument to humanity's love for exploring the Moon.

I happened upon the Heart on the night of July 13, 2024 — just shy of the 53rd anniversary of Apollo 15's July 30, 1971, Moon landing. On a whim, I took out my 3-inch Tele Vue refractor and started sweeping the lunar terminator (the curved line separating the illuminated and shadowed sections of the Moon) at 225x. Suddenly, the lovely feature snapped into view, causing my own heart to skip a beat. At the time of observation, the Moon was 48 percent illuminated, or seven days and 19 hours after New Moon at colongitude 359°.



Despite the fuzziness of the image, the Heart is clearly shown through a 3-inch refractor on the night the author discovered the lunar feature. South is left; lunar west is at top. STEPHEN JAMES O'MEARA

The lovely feature snapped into view, causing my own heart to skip a beat.

The Heart encompasses nearly the entire Palus Putredinis region, otherwise known as the not-so-lovely Marsh of Decay, which has an east-west extent of about 110 miles (180 kilometers). It is bounded by several lunar features, including the Archimedes crater to the west, the Hadley-Apennine region to the east, a beach of highland material near the Autolycus crater to the north, and a U-shaped ridge of highland material west of the southern terminus of Hadley Rille.

The Palus Putredinis region itself is quite fascinating. For instance, the Heart's northwest lobe is formed not by lunar peaks, but by a series of braided wrinkle ridges — volcanic structures formed by tectonic folding, uplift, or compression. At the northern end of these ridges, you'll find the small crescent-shaped crater Spurr, whose ghostly northern rim has been almost totally submerged in ancient lava flows. Beyond Hadley's, you can find several other volcanic rille systems (likely lava channels) to the south of the Heart — such as Rima Bradley, which needles the Heart.

On Sept. 13, 1959, the Soviet Luna 2 became the first spacecraft to make contact with another celestial body when it impacted the Moon next to the northern lobe of the Heart. The crash site lies just southwest of Autolycus. Twelve years later, Apollo 15 would touch down about 160 miles (260 km) from it.

The Moon will be 48 percent illuminated about a week before Valentine's Day, on Feb. 5 at colongitude 353.5°. The next two occasions will occur on March 7 at a colongitude of 358.5° and April 5 at colongitude 351.9°. If these nights are clear, be sure to turn your scopes to the beaded Heart of Palus Petridinis and see if this random assortment of lunar peaks doesn't stimulate your imagination. As always, share your experience at sjomeara31@gmail.com.

BROWSE THE "SECRET SKY" ARCHIVE AT **www.Astronomy.com/OMeara**

TOP 10 SPACE STORIES of 2024

Webb continued to make groundbreaking finds, a massive solar storm ignited aurorae across the globe, and a total solar eclipse wowed North America.

BY ALISON KLESMAN AND MARK ZASTROW

THIS PAST YEAR BROUGHT MUCH OF THE WORLD together through events both anticipated and unexpected. April's highly awaited total solar eclipse delighted millions with the sight of a lifetime — though dodging clouds got a bit stressful for some. Less than a month later, the Sun unleashed a massive storm that lit the skies with dazzling aurorae above locales that rarely see such sights.

Also close to home, scientists found the source of the Moon's thin atmosphere, NASA looked for commercial partners to save its Mars sample-return mission, and astronauts testing Boeing's Starliner became long-term residents of the International Space Station when the craft's thrusters failed to behave as planned. Farther afield, new images of the Milky Way's supermassive black hole hinted it might possess a hidden jet, astronomers discovered the heaviest galactic stellar-mass black hole, and researchers ramped up the search for atmospheric features that might signal life on extrasolar planets.

All the while, the James Webb Space Telescope made brand-new discoveries and added to old ones, continuing to prove that even as one cosmic question is answered, many more are left in its wake.



10 EXOPLANET ATMOSPHERES COME INTO FOCUS

The exoplanet K2-18 b may have an ocean of water beneath a hydrogen-rich atmosphere, as shown in this artist's concept. ILLUSTRATION: NASA, ESA, CSA, JOSEPH OLMSTED (STSCI). SCIENCE: NIKKU MADHUSUDHAN (IOA)

THE JAMES WEBB SPACE TELESCOPE (JWST) is one of the most powerful tools we have in the search for habitable planets with warm, temperate atmospheres. But finding those worlds was never going to be easy.

Perhaps no single exoplanet has been more discussed and debated over the past year than K2-18 b, a planet in the habitable zone of a red dwarf 124 light-years away. At roughly 8.6 times Earth's mass and 2.6 times its girth, scientists aren't sure whether it is a rocky super-super-Earth or a miniature version of hydrogen-rich gas giants like Neptune.

In 2023, researchers using JWST reported that K2-18 b's atmosphere contained carbon dioxide and methane. One interpretation of this data is that the planet has a hydrogen-rich atmosphere but a rocky surface covered with a global water ocean.

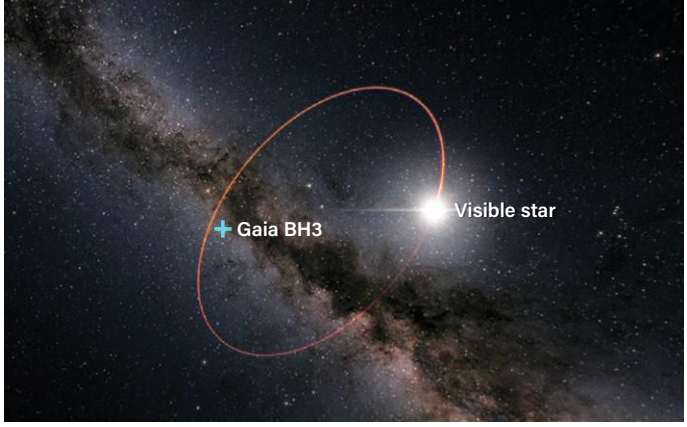
Even more tantalizing, the team reported a possible indication of dimethyl sulfide (DMS), a compound that on Earth is produced only by life — mainly phytoplankton. But the signal on K2-18 b was very tentative, the team noted; even if confirmed, it could be another chemical mimicking the spectral signature of DMS.

On May 2, 2024, a team led by researchers from the University of California, Riverside, reported in *The Astrophysical Journal Letters* that the putative DMS signal was much more likely to be caused by methane. They also concluded that distinguishing DMS from methane at that particular wavelength is probably beyond JWST's capabilities. However, they found it is still possible that very high levels of DMS could be identified in the mid-infrared; JWST results from K2-18 b at those wavelengths are pending.

Days later, another JWST study was published in *Nature*, reporting for the first time strong signs of an atmosphere around an exoplanet that is *definitely* rocky. However, that planet, 55 Canrcri e, is hardly habitable. Orbiting its host star at only 1.5 percent the distance of Earth from the Sun, its dayside temperatures likely reach 4,400 degrees Fahrenheit (2,400 degrees Celsius).

Still, the presence of carbon dioxide and carbon monoxide at 55 Cancri e — and the absence of hydrogen and helium — came as a welcome find: They indicate that what JWST found is not the planet's first atmosphere, but a secondary atmosphere. This means that even if a planet loses its first atmosphere, it can grow another — replenished by volcanic activity and sustained even in the face of its star's radiation. That's good news for anyone hoping that life is common in the galaxy.

9 Gaia discovers an ancient, heavy black hole



Astronomers identified Gaia BH3 (whose position is marked by the cross) not by its bright accretion disk — it doesn't have one — but by watching its visible companion, a giant star, orbit an invisible object. ESA/GAIA/DPAC - CC BY-SA 3.0 IGO. BASED ON GAIA COLLABORATION, P. PANUZZO, ET AL. 2024

SINCE 2013, THE GAIA SATELLITE HAS BEEN MAPPING STARS throughout our Milky Way. Along the way, its data have facilitated numerous discoveries. Among them is Gaia BH3, the heaviest-known stellar-mass black hole in our galaxy to date.

Stellar-mass black holes are left when a massive star ends its life as a supernova. They range from a few to 100 times the mass of our Sun. Since Cygnus X-1's discovery as the first stellar-mass black hole, it had also reigned supreme as the Milky Way's heaviest, at 21 solar masses.

Now it's been outdone by a dark, dormant black hole nearly four times closer to Earth.

Gaia BH3 is in a binary system with a star 1,926 light-years away. Astronomers spotted it in preliminary Gaia data meant to be released in 2026 — but the find was so exciting they couldn't wait, publishing it May 27 in *Astronomy & Astrophysics*.

Gaia BH3 is not pulling in matter and doesn't have a bright accretion disk to give it away. Instead, the motion of the visible star revealed an invisible companion weighing 33 solar masses. Nothing so massive could also be dark — except a black hole.

"It's the first time a black hole of this size has ever been observed, with the exception of those detected in distant galaxies by the LIGO-Virgo gravitational observatories," said study lead author and Gaia collaboration member Pasquale Panuzzo of CNRS, Observatoire de Paris, France, in a press release. "This is the kind of discovery you make once in your research life."

In addition to breaking the weight record, Gaia BH3 is also shedding light on how such massive black holes form. Aging

8 NASA rethinks Mars Sample Return



In the now-postponed NASA-ESA Mars Sample Return mission, the Perseverance rover and helicopter drones would bring rock samples to a lander, from which an ascent vehicle would carry the samples to a return orbiter. NASA has since sought help from industry to simplify this scheme. NASA/ESA/JPL-CALTECH

THE CAR-SIZED PERSEVERANCE rover has spent four years on Mars wheeling across the ancient lakebed of Jezero Crater, drilling and caching rock samples so that, for the first time ever, martian rock samples can be returned to Earth for close-up study. The samples were meant to be retrieved by a set of joint NASA-European Space Agency (ESA) missions over the next decade. But plans for the samples' journey home are now crumbling in the face of budget struggles.

The mission, called Mars Sample Return (MSR), originally called for NASA to send a lander with an ESA-built rover to fetch the samples. The lander's ascent stage, called the Mars Ascent Vehicle (MAV), would loft the precious cargo to martian orbit to be captured by a European orbiter, launched separately, that would whisk them back to Earth in 2031.

The complexity of this scheme had already prompted multiple rethinks. In March 2022, NASA officials said they planned to launch the MAV and the ESA fetch rover on separate spacecraft to reduce risk, with return scheduled for 2033. Then, four months later, NASA and ESA said the fetch rover would be scrapped entirely. Instead, in 2030, Perseverance — which will then be going on a decade old — would deliver its own samples to the retrieval lander. As a backup, the lander would also bring two helicopter drones that could nab the samples and fly them to the MAV.

At the same time, MSR's funding was drying up. In Congress, budget negotiations left NASA with a 2 percent budget cut in 2024. MSR was hardest hit. On Feb. 6, 2024, the Jet Propulsion Laboratory in Pasadena, which has designed, built, and operated all of NASA's Mars rovers, laid off 530 staff — around 8 percent of its workforce.

On April 15, NASA announced the entire MSR mission was on hold and needed an overhaul. Under the existing plans, the agency estimated, the samples would not arrive on Earth until 2040, and it would cost up to $11 billion. Effectively, NASA was admitting it was out of money, out of time, and out of ideas.

To get the rocks back more cheaply and quickly, in June, NASA commissioned studies from seven

stars blow away much of their mass through winds, leaving less material to create a heavy black hole. But stars born earlier in the cosmos' history were more massive and may have had weaker winds, thus leaving behind more massive black holes.

Backing up that story is its companion: an old, metal-poor star, meaning it has few elements heavier than hydrogen or helium. Stars are essentially metal manufacturers. Each generation of stars enriches the cosmos, so that younger generations contain more metals at their birth. Metal-poor stars are therefore from earlier in cosmic time. And based on its motion, the pair likely once belonged to a globular cluster that has long since been cannibalized by the Milky Way.

All this points to Gaia BH3 as a relic from the cosmos' ancient past, hiding in plain sight. Furthermore, "this discovery should be also seen as a preliminary teaser for the content of Gaia DR4," the paper concludes, "which will undoubtedly reveal other binary systems hosting a [black hole]."



firms — including Lockheed Martin, SpaceX, and Blue Origin — with various concepts and ideas for revising the mission architecture. NASA also indicated it is willing to consider proposals that would return as few as 10 samples, down from the 30 originally hoped for. The studies were due back to NASA in October.

In the meantime, China has announced plans to launch its own Mars sample-return mission, Tianwen-3, as early as 2028. Time will tell who can actually pull off the multi-planet effort.

7 Meteorites create the Moon's atmosphere



EARTH'S MOON IS A LIGHTWEIGHT. While it looms large in our skies, its gravity is not strong enough to hold onto a bulky atmosphere. But it does retain a thin blanket of atoms, called an exosphere.

Planetary scientists know this exosphere is generated through space weathering, as interactions between the Moon's surface and incoming meteorites and solar radiation generate atoms to replenish it. Without this, the exosphere would dissipate as its atoms drifted out to space. But exactly which process — or combination of them — are most important remained unknown, until researchers at MIT and the University of Chicago used soil collected by Apollo astronauts to determine last year that meteorites are the main culprit. Their work was published Aug. 2 in *Science Advances*.

Analysis of soil samples retrieved by Apollo astronauts show that meteorite strikes are largely responsible for liberating the atoms that form the Moon's thin atmosphere. ALAN DYER

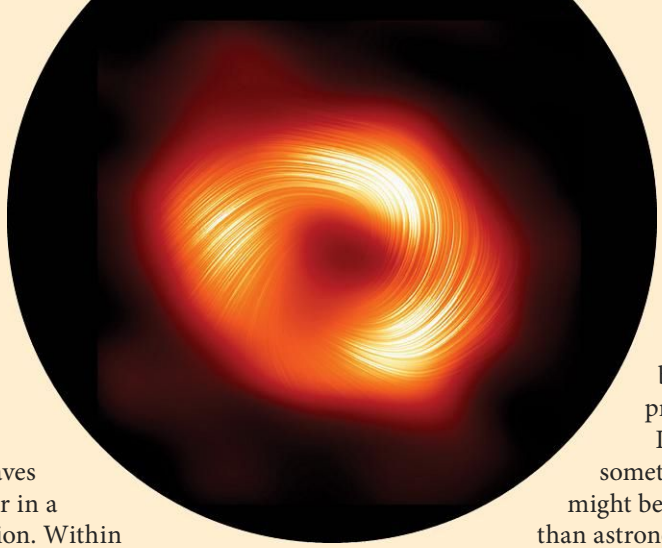
From 10 samples, they isolated two elements — potassium and rubidium — to measure the isotopes of each in the soil. Isotopes of a given element contain the same number of protons but a different number of neutrons in the nucleus; isotopes with more neutrons are heavier. The soil preferentially contained heavier isotopes, as expected. When meteorites or radiation slam into the lunar surface, it vaporizes bits of soil. Lighter isotopes should float up to create the exosphere, while heavier isotopes fall back to the ground, but different space weathering processes leave different amounts of heavy isotopes. Comparing the ratio of isotopes of potassium and rubidium in the soil held the key to how they were released.

"The reason why we look at the ratio instead of just one isotopic system is because it can help remove many complexities and isolate the effects of certain processes. Both rubidium and potassium are moderately volatile elements with similar geochemical behaviors, meaning they tend to respond similarly to many processes, like melting and vaporization. When we look at their isotopic ratio, we're essentially filtering out the common effects of these processes that would affect both elements similarly," says study lead author Nicole Nie of MIT. Comparing the elements means "we're not trying to disentangle multiple effects on a single isotopic system. Instead, we can simplify the interpretation and get clearer insights into … space weathering processes," she says.

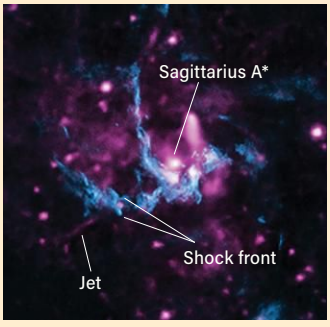
The ratios show that impact vaporization is creating the majority — some 70 percent — of the atoms in the Moon's atmosphere, while solar wind reactions are responsible for the other 30 percent.

The result "is crucial for gaining insights into the space weathering processes that have shaped the lunar surface," Nie says. "It enhances our understanding of planetary evolution. … These interactions are not unique to the Moon; they occur on other airless bodies like Mercury, asteroids, and moons of planets, so insights from the lunar exosphere can be applied to understanding surface processes across the solar system."

6 Sgr A* may have a jet



ABOVE: The Event Horizon Telescope produced this image of the Milky Way's supermassive black hole, Sgr A*, in polarized light. The lines show the orientation of the polarization of the light received, which traces the black hole's magnetic field and shows a strong, ordered structure. EHT COLLABORATION



LEFT: When viewed in X-rays (pink) and radio emission (blue), Sgr A* also shows tantalizing hints of a jet: a shock front where particles are slamming into the surrounding material, as well as a straight line of hot gas that is emitting X-rays. X-RAY: NASA/CXC/UCLA/Z.LI ET AL; RADIO: NRAO/VLA

IT HAS BEEN NEARLY THREE YEARS since the Event Horizon Telescope (EHT) revealed its image of Sagittarius A* (Sgr A*), the Milky Way's 4-million-solar-mass supermassive black hole. But one picture is never enough. Last year, the EHT team released an image of Sgr A* in polarized light, alongside two papers published March 27 in *The Astrophysical Journal Letters*.

Polarization refers to the orientation of the electromagnetic waves that make up light. When light is polarized, its waves oscillate together in a preferred direction. Within a black hole's accretion disk of swirling, superheated plasma, magnetic field lines can align the moving particles such that they emit polarized light, essentially stamping their emission with an afterimage of the embedded magnetic field. So, examining polarization reveals a picture of the magnetic field around the black hole.

In polarized light, Sgr A* appears remarkably similar to the other black hole imaged this way: M87* in the elliptical galaxy M87. This is despite the fact that Sgr A* is roughly a thousand times less massive — and a thousand times smaller, with the plasma around it moving much quicker — than M87*, hinting that strong, ordered magnetic fields might be more ubiquitous around supermassive black holes than previously thought. It also hints at something else that might be more widespread than astronomers thought: jets. Many of the most massive black holes, including M87*, launch far-reaching jets from their accretion disks, powered by magnetic fields. So, if Sgr A*'s magnetic field is so similar to that of more massive black holes, could it host a jet like they do as well?

No jet has ever been seen blasting from our black hole, but the search is on. And the polarized light image is still a powerful tool, as small tweaks to model inputs can create big changes in the polarization produced, allowing researchers to better understand the conditions around our supermassive black hole.

5 Eclipse ecstasy

AFTER YEARS OF ANTICIPATION AND HYPE, the total solar eclipse of April 8, 2024, made good on its promises, giving tens of millions of viewers a chance to revel in the majesty of the Sun's corona.

The eclipse was almost certainly the most-viewed in the history of the U.S. Seven years prior, the Great American Eclipse of 2017 had cut across the nation from coast to coast, with 12 million people living in the path of totality. In 2024, that number was 31 million in the U.S., as the path blanketed major metro areas from Texas to the eastern seaboard. In fact, half the entire U.S. population lived within 250 miles of totality.

Not only that, in 2024 Mexico and Canada joined the party. Making landfall in Mazatlán, the shadow of the Moon swept through Durango and the Chihuahuan Desert and on into Texas and the U.S. Midwest before straddling the U.S.-Canadian border and departing the continent via Newfoundland.

In the days leading up to the eclipse, forecasts of widespread clouds threatened to dampen the excitement. At one point, forecast models predicted that most of the U.S. would be clouded out. But come eclipse day, the bulk of the cloud cover failed to materialize, and most along the path enjoyed clear skies — or high, thin cloud layers that didn't interfere with the Sun's visual appearance.

Researchers took advantage of the eclipse, too. NASA awarded funding to five science projects, including chasing the eclipse with high-altitude research jets, radio-telescope observations of sunspot regions, and radar studies of the effects of the Sun's shadow on Earth's ionosphere. It turns out there is still plenty of opportunity to discover something new under the Sun and the Moon.



2024's total solar eclipse gave millions a stunning view of an active Sun, with fine streams of plasma emerging from the Sun's surface. BRENT BOWEN

4 Starliner test flight strands astronauts



RIGHT: NASA astronauts Butch Wilmore (left) and Suni Williams planned on a weeklong visit to the ISS, but ended up staying in space for eight months as a more permanent part of the crew. NASA

BELOW: The Boeing Starliner consists of a reusable Crew Module and a single-use Service Module. The Service Module houses 28 thrusters, five of which malfunctioned during the spacecraft's first crewed test flight last year. It is also the portion of the craft that experienced three helium leaks. The four compartments housing the thrusters could not be accessed in space, nor could the misbehaving thrusters be examined on the ground, as the Service Module is jettisoned during reentry and burned up in Earth's atmosphere. However, the detailed data recorded during the reentry procedure is helping engineers determine what caused the issue. NASA

AT 10:52 A.M. EDT ON JUNE 5, 2024, NASA astronauts Butch Wilmore and Suni Williams lifted off from Cape Canaveral, Florida, on the Boeing CST-100 Starliner capsule's long-awaited first crewed test flight.

During its journey to the International Space Station (ISS), however, Starliner's propulsion system developed two helium leaks (in addition to one noted prior to launch), as well as issues with five of its 28 thrusters. Nonetheless, it successfully docked with the ISS and Wilmore and Williams prepared to spend about a week in space before piloting the craft back to Earth.

Instead, the empty Starliner touched down at White Sands Space Harbor in New Mexico at 12:01 A.M. EDT on Sept. 7, while Wilmore and Williams remained in orbit for a total of eight months, to return aboard a SpaceX Dragon capsule in February 2025.

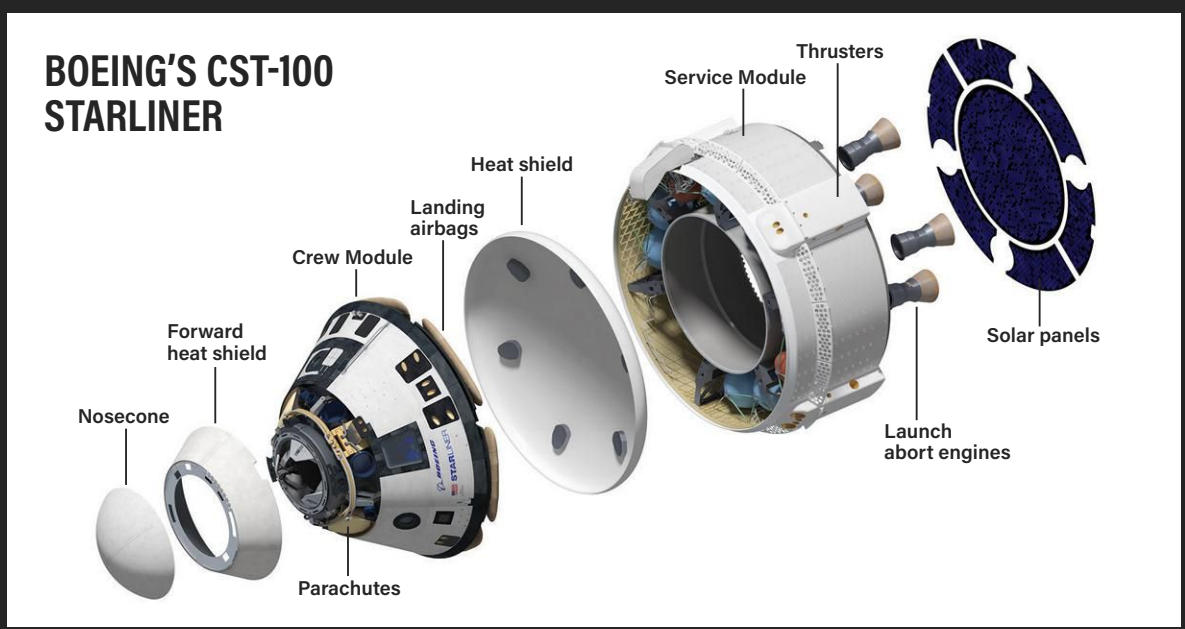
At first, NASA simply delayed the astronauts' return, as the space agency and Boeing worked to determine what had caused Starliner's thrusters — vital to both maneuver in space and to set the craft on a trajectory home — to malfunction. But on Aug. 24, NASA announced it would bring Starliner back uncrewed, instead adjusting the SpaceX Crew-9 mission, which launched Sept. 28, to leave two empty seats in its Crew Dragon capsule for Wilmore and Williams to return home at that mission's end.

"When we looked at the data and looked at the potential for thruster failures [during undocking and deorbit] with a crew on board … it was just too much risk with the crew, and so we decided to pursue the uncrewed test flight," said Steve Stich, manager of NASA's Commercial Crew Program, during a press conference to announce the decision.

Wilmore and Williams, both veteran ISS occupants, took the extra time in space in stride. "That's how things go in this business," Williams said in September from the station, emphasizing the uncertain nature of test flights. "This is my happy place. I love being up here in space," she added.

On Sept. 6, Starliner left the ISS and completed all maneuvers via automation and without issue, parachuting to a landing in the New Mexico desert just after midnight local time. Its return flight data went into the hands of engineers for meticulous evaluation to determine whether changes to the thrusters might be necessary before it can be certified for crewed missions.

"We knew going in this was going to be a test mission," said NASA Deputy Associate Administrator for Space Operations Joel Mantalbano, following Starliner's return. "We learned a lot. … To me, [this was] a success. Clearly we [have] some work to do."





3 Sun's wrath thrills solar storm chasers

FOR LOVERS OF SOLAR OBSERVING, 2024 was a year of spoils. In addition to April's total eclipse, the Sun reached the peak of its 11-year cycle of activity.

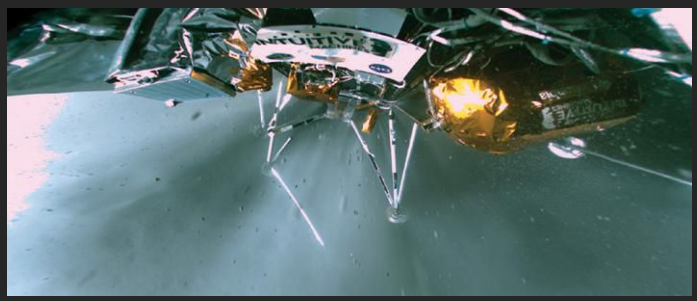
Because the Sun's gas rotates faster at its equator than at the poles, our star slowly winds itself up, its magnetic field lines twisting up like rubber bands. Every 11 years, they begin to snap, releasing explosive bursts of energy.

In 2024, sungazers were treated to dazzling displays of sunspots, prominences, and flares. These were often accompanied by coronal mass ejections (CMEs) — storms of plasma that speed through the solar system. When a CME slams into Earth's magnetic field, it can produce geomagnetic storms and strong displays of aurorae. And when the Sun spits out several in succession, they can merge

2 Back to the Moon

NEVER MIND THE HUMANS. In 2024, a flotilla of robotic explorers trekking to the Moon ushered in a new golden age of lunar exploration.

The first robotic lunar landers, from the U.S. and former USSR, touched down in 1966. Forty-seven years passed before China became the third nation to achieve a soft lunar landing, with 2013's Chang'e 3. But a dizzying 10 months across 2023 and 2024 saw two new nations join that exclusive club, as well as the first soft lunar landing from a private company, and also the first rocks returned from the Moon's farside.



The private IM-1 mission resulted in a soft landing for the Odysseus spacecraft, despite breaking a leg as it skidded on touchdown. INTUITIVE MACHINES

On Aug. 23, 2023, India made its first lunar landing with the Chandrayaan-3 mission, depositing the Vikram lander and the Pragyan rover just 390 miles (630 kilometers) from the Moon's south pole. The craft and their suite of scientific instruments operated for 12 Earth days, until the fall of lunar night, meeting their design lifespan.

Then 2024 kicked off with Japan's Smart Lander for Investigating Moon (SLIM) mission, dubbed the "Moon Sniper" for its main goal: making a precision landing within 330 feet (100 meters) of its planned target. The craft hit that mark on Jan. 19, although it tipped over on landing, depriving its solar panels of power. But 10 days later, as the Sun shifted in the Moon's airless sky, it was able to recharge and awaken, sending back data and images. Though not designed to survive the lunar night — which lasts 14 Earth days — the craft unexpectedly survived three of them, making its last contact in April.

Another major milestone arrived Feb. 14, when the Houston-based company Intuitive Machines became the first company to make a soft lunar landing with its Odysseus lander. It achieved this despite a wiring error that disabled its laser rangefinders. Odysseus skidded hard on landing, breaking a leg and coming to rest at a tilt. Still, like SLIM, it was a historic milestone, even if the orientation of the craft limited operations for some of the six scientific experiments that it carried for NASA. (The mission was

LEFT: The convergence of half a dozen coronal mass ejections led to a stunning display of aurora on the night of May 10/11, including in this image, over the bright city skyline of Vancouver. ROB LYONS

LEFT INSET: The colossal sunspot group AR3664 spanned more than 15 Earth diameters and unleashed some of the strongest flares of this solar cycle. ROB LYONS

RIGHT: The historic storm was captured by millions on smartphones, including here at the Ashokan Reservoir in New York. CHIRAG UPRETI



and strike with combined strength.

In early May, a gargantuan sunspot group, AR3664, unleashed half a dozen CMEs within a few days, generating a perfect storm that raced toward Earth at up to 3 million mph (4.8 million km/h). In response, the Space Weather Prediction Center (SWPC) at the National Oceanic and Atmospheric Administration issued a severe geomagnetic storm watch, warning power companies to protect their grids and GPS users to prepare for potential disruptions. It was the first G4-level watch — the second highest level, behind G5 — in nearly 20 years.

As night fell across Europe on May 10, it quickly became clear that the storm was exceeding expectations. Social media was flooded with pictures of skies ablaze with brilliant greens and magentas over European cities and the snow-covered Alps.

At 6:54 P.M. EDT, SWPC reported the storm had hit G5 conditions. In North America, aurorae were spotted in Cuba and Mexico. Globally, cameras captured aurorae as far south as the Hanle Dark Sky Reserve in India, and as far north (in the Southern Hemisphere) as Namibia.

The last geomagnetic storm of comparable magnitude was in 2003. But in terms of the human experience, there was no precedent. In 2003, the iPhone, Facebook, and YouTube didn't exist. With the advancement of sensor technology, most people on the planet carry a camera in their pocket capable of capturing aurorae and sharing it instantly. In the 7 million or so years since primates have been walking upright across our planet and gazing up at glowing curtains of light in the night sky, the May 2024 auroral storm was a first.

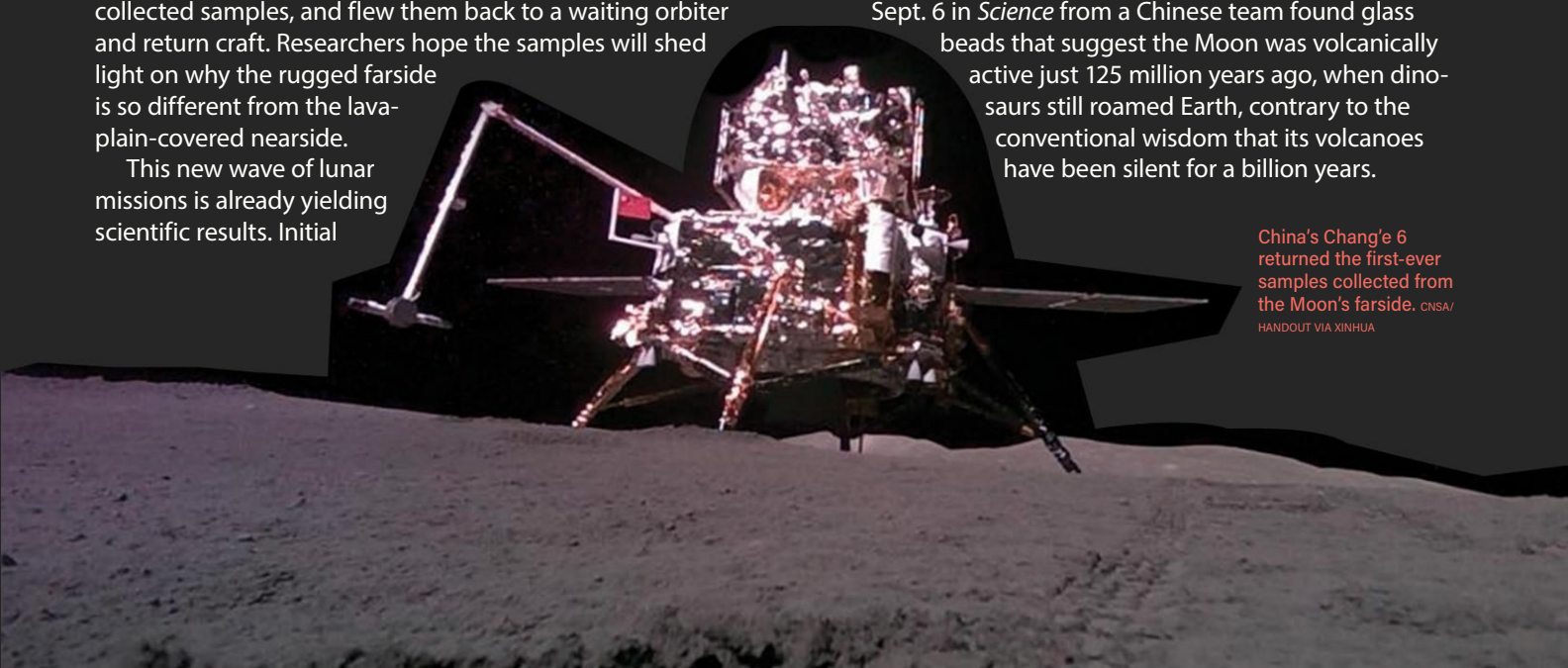
This thrills scientists, who now have a veritable treasure trove of citizen-science data to study. But it also made for an extraordinary communal sky-watching event, like a great comet or total eclipse, that will be remembered for decades to come.

funded by NASA as part of its Commercial Lunar Payload Services program.)

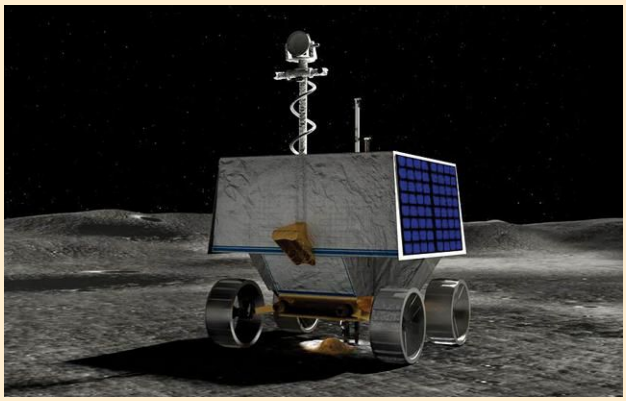
Then, on June 1, China scored its latest achievement — collecting the first-ever samples from the Moon's farside, with its Chang'e 6 mission. The mission was based on the Chang'e 5 architecture, but China's delivery of a Moon-orbiting relay satellite allowed it to communicate as it landed on the farside in the South Pole-Aitken impact basin, collected samples, and flew them back to a waiting orbiter and return craft. Researchers hope the samples will shed light on why the rugged farside is so different from the lava-plain-covered nearside.

This new wave of lunar missions is already yielding scientific results. Initial analysis of Pragyan data published in *Nature* Aug. 21, 2024, revealed that the composition of rocks at its landing site is very similar to samples returned from the Apollo 16 and Luna 20 sites, over 1,000 miles (1,600 km) north. This strengthens the case that these rocks were once part of a global ocean of magma that coated the Moon's surface soon after its formation.

And scientists are still gleaning information from the samples returned by the 2020 Chang'e 5 mission. A study published Sept. 6 in *Science* from a Chinese team found glass beads that suggest the Moon was volcanically active just 125 million years ago, when dinosaurs still roamed Earth, contrary to the conventional wisdom that its volcanoes have been silent for a billion years.



China's Chang'e 6 returned the first-ever samples collected from the Moon's farside. CNSA/HANDOUT VIA XINHUA



VIPER, depicted here on the lunar surface, would have been the first robotic rover capable of operating at night. NASA/DANIEL RUTTER

BUDGET SHORTFALLS THREATEN NASA'S FUTURE

COST-CUTTING TOOK A TOLL ON OTHER NASA MISSIONS IN 2024.

On July 17, NASA stunned the scientific community by cancelling the mission of a $450 million Moon rover that had already been built. The Volatiles Investigating Polar Exploration Rover (VIPER) was meant to search for water ice near the lunar south pole in preparation for future Artemis crews that might take up residence in the vicinity. It only needed to pass environmental testing and be loaded onto its rocket for a 2025 launch. Looking to cut costs, NASA offered to give the rover away, free of charge, to any company or organization that was willing to bear the cost of flying it to the Moon and carrying out its original mission.

Meanwhile, the Chandra X-ray telescope spent 2024 celebrating 25 wildly productive years of observations while simultaneously being led to the guillotine. While still fully functional as the highest-resolution X-ray telescope in the sky, in March, NASA said it would lay off most of its staff later in the year. NASA also indicated in its 2025 budget request that it planned to draw the mission down to "minimal operations" — a prelude to shuttering the scope for good. Scientists responded with an extraordinary outcry and several members of Congress joined them, leading NASA to announce Oct. 23 that it would stay the observatory's execution until Congress appropriates funds for 2025.

These issues are symptoms of a broader malaise at NASA, which was laid bare in a comprehensive report titled *NASA at a Crossroads* released Sept. 11 by the National Academies of Sciences, Engineering, and Medicine (NASEM). The body is also responsible for the influential astronomy and planetary science decadal reviews, which guide Congress, NASA, and other funding agencies in deciding which projects to prioritize.

The crux of NASA's issues is that the agency's purchasing power has remained essentially flat over the past two decades, yet it is directed to take on more projects than ever. This push for more missions comes at the expense of maintaining NASA's existing resources and infrastructure. The NASEM report stated that "during its inspection tours, the committee saw some of the worst facilities many of its members have ever seen." The report singled out the Deep Space Network — NASA's global network of radio dishes responsible for communicating with everything from JWST to the Voyager probes — as particularly stretched and in dire need of upgrades.

The report also criticized NASA's own lack of long-term strategic planning, particularly in the Artemis program. And the committee warned that relying on the commercial sector to develop and carry out its missions risked NASA morphing into a mere contract monitor and losing its workforce to more inspiring organizations and companies. —*M.Z.*

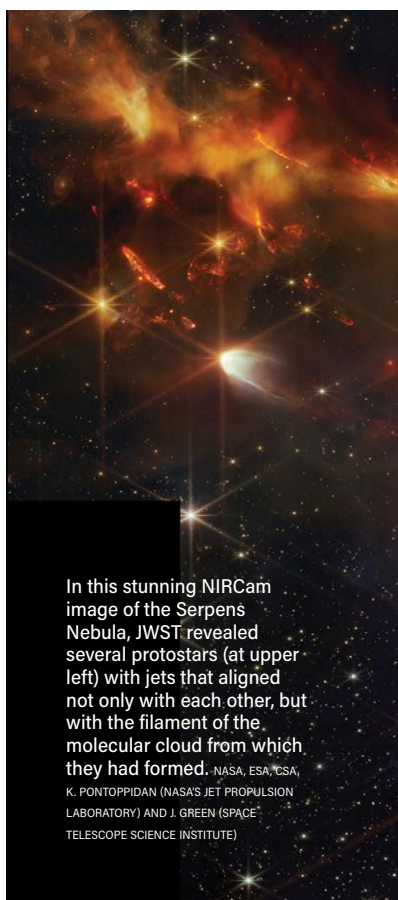
1 JWST makes more discoveries — and offers some answers

UNSURPRISINGLY, THE JAMES WEBB SPACE TELESCOPE (JWST) makes our list yet again. Although it made too many discoveries to mention them all, we're highlighting a few 2024 finds across a wide range of fields, from planets and stars to some of the biggest questions about the cosmos' early history.

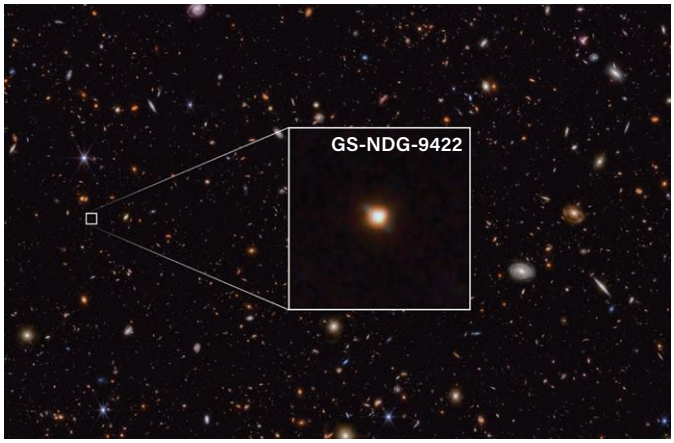
In a Feb. 22 *Science* paper, JWST provided the best evidence yet for the neutron star astronomers believe was left behind by the supernova SN 1987A in the Large Magellanic Cloud. The infrared scope spotted the glow of ionized gas whose atoms — called ions — have had several electrons knocked off by high-energy photons. "To create these ions that we observed in the ejecta, it was clear that there had to be a source of high-energy radiation in the center of the SN 1987A remnant," said lead author Claes Fransson of Stockholm University in a press release. "Only a few scenarios are likely, and all of these involve a newly born neutron star."

In April, JWST showed off its exoplanet science chops after observing starlight filtering through the atmosphere of the gas giant WASP-43 b. By combining information about the molecules the telescope saw with 3D climate models, researchers were able to map the planet's weather from 280 light-years away: a cloudy nightside, a clear dayside, and winds at the equator reaching some 5,000 mph (8,050 km/h).

A June release highlighted another JWST first: The discovery of aligned jets from a group of forming stars. Astronomers had long suspected that stars born from the same molecular cloud should rotate in the same direction, imparted by the cloud's motion. But they had never observed such alignment until JWST's sharp eye caught some 20 protostars in the Serpens Nebula, with jets all aligned within 24° of the axis of the filament that had formed them.



In this stunning NIRCam image of the Serpens Nebula, JWST revealed several protostars (at upper left) with jets that aligned not only with each other, but with the filament of the molecular cloud from which they had formed. NASA, ESA, CSA, K. PONTOPPIDAN (NASA'S JET PROPULSION LABORATORY) AND J. GREEN (SPACE TELESCOPE SCIENCE INSTITUTE)



JWST spotted the galaxy GS-NDG-9422 (inset) at a time when the cosmos was just 1 billion years old. Its gas is outshining its stars, offering a look at how early stars energized their surroundings. NASA, ESA, CSA, STSCI, ALEX CAMERON (OXFORD)

And if you recall last year's list, you might remember the potentially "universe-breaking" galaxies JWST turned up less than a billion years after the Big Bang: six galaxies shining so brightly that astronomers suspected they contained up to 100 billion solar masses' worth of stars each. Galaxies so massive should not form so quickly, prompting concerns about our understanding of how early matter assembled.

Since then, researchers have been working to explain the finding. In an August paper published in *The Astronomical Journal*, a team using data from JWST's Cosmic Evolution Early Release Science survey showed that the galaxies have normal masses and are instead getting a brightness boost from the accretion disks around their central supermassive black holes. New JWST observations showed the signature of hot, fast-moving gas in these galaxies — a hallmark of the accretion disk around a black hole.

"The bottom line is there is no crisis in terms of the standard model of cosmology," said study co-author Steven Finkelstein, a professor of astronomy at the University of Texas at Austin.

Although the galaxies did not grow faster than expected, "we are still seeing more galaxies than predicted" at this early time by roughly a factor of two, said lead author Katherine Chworowsky, also of UT Austin. Astronomers wonder if this strange result might be because early stars still formed relatively quickly, more easily assembling into galaxies.

So, while one mystery is solved, another has popped up. Stay tuned — perhaps next year JWST will shed even more light on this new cosmic conundrum.

STORIES TO WATCH FOR IN 2025

- NASA's Lucy mission to explore Jupiter's Trojan asteroids will fly by the carbonaceous main-belt world 52246 Donaldjohanson on April 20, while on its way to the gas giant.
- The Vera C. Rubin Observatory in Chile is scheduled to see first light May 16, 2025. The observatory will then undergo a review for operations readiness in mid-August.
- NASA's ambitious Artemis II mission, which will send four astronauts on a 10-day journey around the Moon, is targeting a launch no earlier than September 2025.
- NASA's Commercial Lunar Payload Services initiative has three launches planned for 2025. Griffin Mission 1 will test Astrobotic's lander (sans the canceled VIPER rover); Lunar Pathfinder will place an orbiter around the Moon; and Intuitive Machines 3 will transport several payloads, including a data-relay satellite and a rover.



Alison Klesman *and* **Mark Zastrow** *are senior editors of* Astronomy.


Treasures
of the
MILKY



WAY

Let's talk about objects along the plane of the galaxy. BY ADRIAN BRADLEY

I BEGAN PHOTOGRAPHING THE MILKY WAY around 2018, but the hobby took off in earnest for me at the onset of the COVID years as I took myself out to remote dark sites to capture images. For many observers, the Milky Way's prime attraction is the northern galactic bulge from the Large Sagittarius Star Cloud up to the territory of Aquila the Eagle. Northern Hemisphere observers will be very familiar with this region's likeness. Its appearance in the sky during the spring and summer months is often referred to as "Milky Way season," but it contains smaller treats within its expanse.

While numerous Milky Way photographers will prominently feature the galactic bulge when they compose wide-field images, they may not be well versed in the many individual objects in this region that are worthy of further exploration.

Hidden treasures reside along the plane of the northern galactic bulge, ranging from Scorpius to Serpens Cauda. (Serpens Cauda is a lesser-known constellation and sits on the side of the galactic bulge, above Scutum and emanating from the Snake Charmer himself, Ophiuchus.) The objects that follow include targets for the Milky Way photography enthusiast, the visual observer with plenty of aperture, and even those with no equipment at all.

Naked-eye observation

There are many bright nebulae and star clusters in this region to observe and image, but a few should get a little more attention, beginning with those that can be seen with the naked eye.

In brighter, more light-polluted skies, look for M11, the Wild Duck Cluster. Start at Lambda (λ) Aquilae in the tail of the Eagle. Follow a hook shape of smaller, fainter stars down toward the horizon. M11 is in the bottom of this circlet. It will look like another star, but in fact you're seeing light from a large open cluster.

← The Milky Way has objects to thrill astronomers of all types, from naked-eye observers to those with the biggest camera and telescope setups. ADRIAN BRADLEY

A MEASURE OF DARKNESS

The darkness of a sky is measured in magnitudes per square arcsecond (mag/arcsec^2), often with an instrument called a sky-quality meter. Readings of less than 20 mag/arcsec^2 indicate a sky surrounded by light pollution. Darker skies have more contrast, and in very dark skies (approaching 22 mag/arcsec^2) you can see all of the regions of the Milky Way very clearly. When I saw our galaxy under truly dark skies for the first time, I thought, "This looks the way I see it when I take pictures!" —*A. B.*

It takes dark skies to find without aid, but the Dark Horse Nebula can be seen prancing across the sprawl of the Milky Way. JOHN CHUMACK

Messier 11, also called the Wild Duck Cluster, is an open cluster found at the juncture of the constellations Scutum the Shield and Aquila the Eagle. ANTHONY AYIOMAMITIS

M11, THE WILD DUCK CLUSTER, WILL LOOK LIKE ANOTHER STAR, BUT IN FACT YOU'RE SEEING LIGHT FROM A LARGE OPEN CLUSTER.



Folks who live under darker skies should recognize the large dark nebula in Ophiuchus that's called the Dark Horse Nebula (also known as the Prancing Horse or the Great Dark Horse). In fact, many dark nebulae along the galactic plane become visible under dark skies, including the Great Rift, which sprawls from Cygnus to Centaurus. To find the Dark Horse, look to the right of the bright region called the Large Sagittarius Star Cloud. If the galactic center is rising, the horse shape is upside

down. The horse's legs reach out to the nearby constellation of Scorpius.

Small binoculars

If you're armed with binoculars, a fainter set of targets start to shine. In brighter skies, see if you can find the open cluster IC 4756 in Serpens Cauda (the tail of the snake). It registers an overall magnitude of 5, and will fill your binocular view with stars. This cluster sits near NGC 6633, a slightly brighter open cluster, and is in the middle of a line between NGC 6633 and the star Alya (Theta [θ] Serpentis) in Serpens. To star hop to it, follow a line from the heart of the Eagle, Delta (δ) Aquilae, to Alya, and continue for about 7 degrees. The first open cluster you get to is IC 4756.

In dark skies, try your luck with dark nebulae. Barnard's E (composed of two dark nebulae, more officially cataloged as Barnard 142 and 143) sits 1.6 degrees west-northwest of Tarazed, (Gamma [γ] Aquilae). Barnard 143 appears as the letter U, where the open portion points west and Barnard 142 is the dark nebula to its north.

Telescopic targets

Now we reach the telescopic treasures. Located in the constellation Scutum, open cluster M26 is a good target for somewhat-light-polluted skies. To find it, follow a line running from Alpha (α) Scuti to Delta Scuti.



Barnard's E darkens the sky less than 2 degrees west-northwest of Tarazed (Gamma Aquilae), the red star seen here. Farther south is bright blue Altair (Alpha Alquilae). ALAN DYER

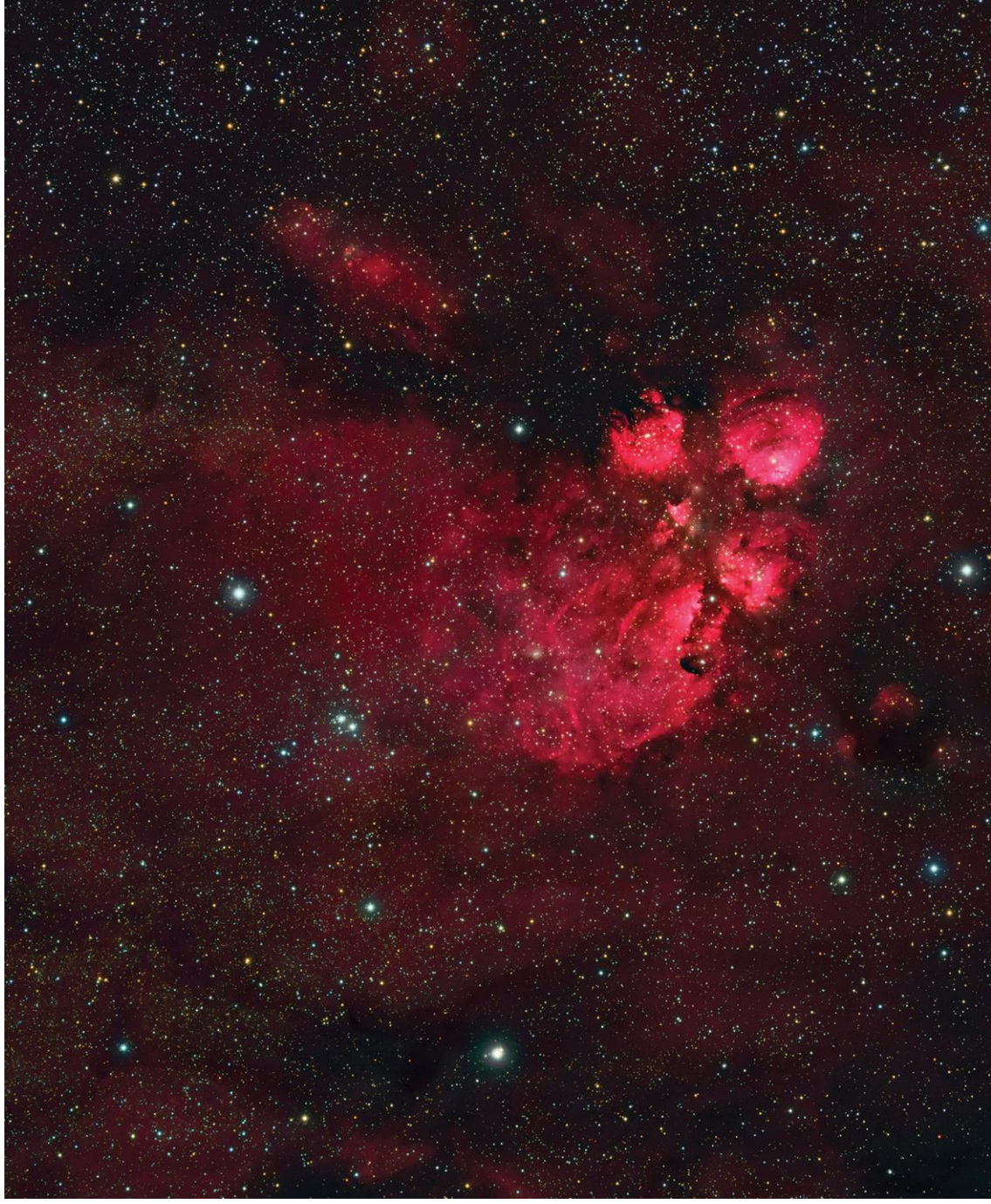


Messier 26 is an often overlooked open cluster approximately one degree east of Delta Scuti. ANTHONY AYIOMAMITIS



Famously captured by the Hubble Space Telescope, the Pillars of Creation in Messier 16 can reveal themselves even from Earth's surface with a large aperture telescope and some narrowband filters. R. JAY GABANY

A WONDERFUL IMAGING TARGET IS NGC 6334, THE CAT'S PAW NEBULA, 3° WEST OF SHAULA (LAMBDA SCORPII), THE TIP OF THE SCORPION'S TAIL.



→ The Cat's Paw Nebula, aka Gum 64 or NGC 6334, glows with light from newly formed stars, which puff out clouds of dust and gas to form the bubbles that resemble the soft underside of cat toes. THOMAS V. DAVIS

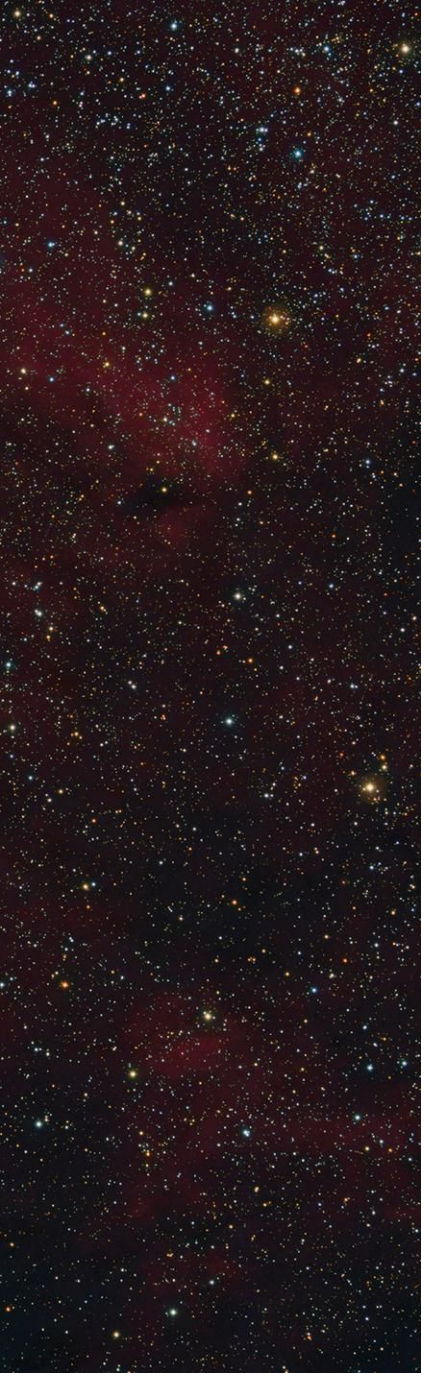
↓ Think you've seen everything? This small nebula, known as Drechsler 29, was only discovered in 2019. CARL BURTON



Continue for 1°, and look for a region that's even more densely packed with stars than the surrounding area.

When the skies are dark enough and you want a challenge, look for NGC 6144, a globular cluster about 40' west of Antares (Alpha Scorpii). NGC 6144 is a 9th-magnitude globular cluster, not to be confused with the much brighter M4 cluster, about 1° to the southwest. I've seen NGC 6144 in an 8-inch telescope under fairly dark skies. If you put Antares in a wide-field view with a 25mm eyepiece or larger, the faint globular cluster should show itself clearly.

If you venture out with a lot of aperture and a good set of filters, I suggest going after the Pillars of Creation in the Eagle Nebula (M16). Even in somewhat brighter skies, the pillars should pop visually. In really dark skies, I suggest Barnard 283 above the tail of Scorpius. It's located near M7, roughly 1° to the northwest.

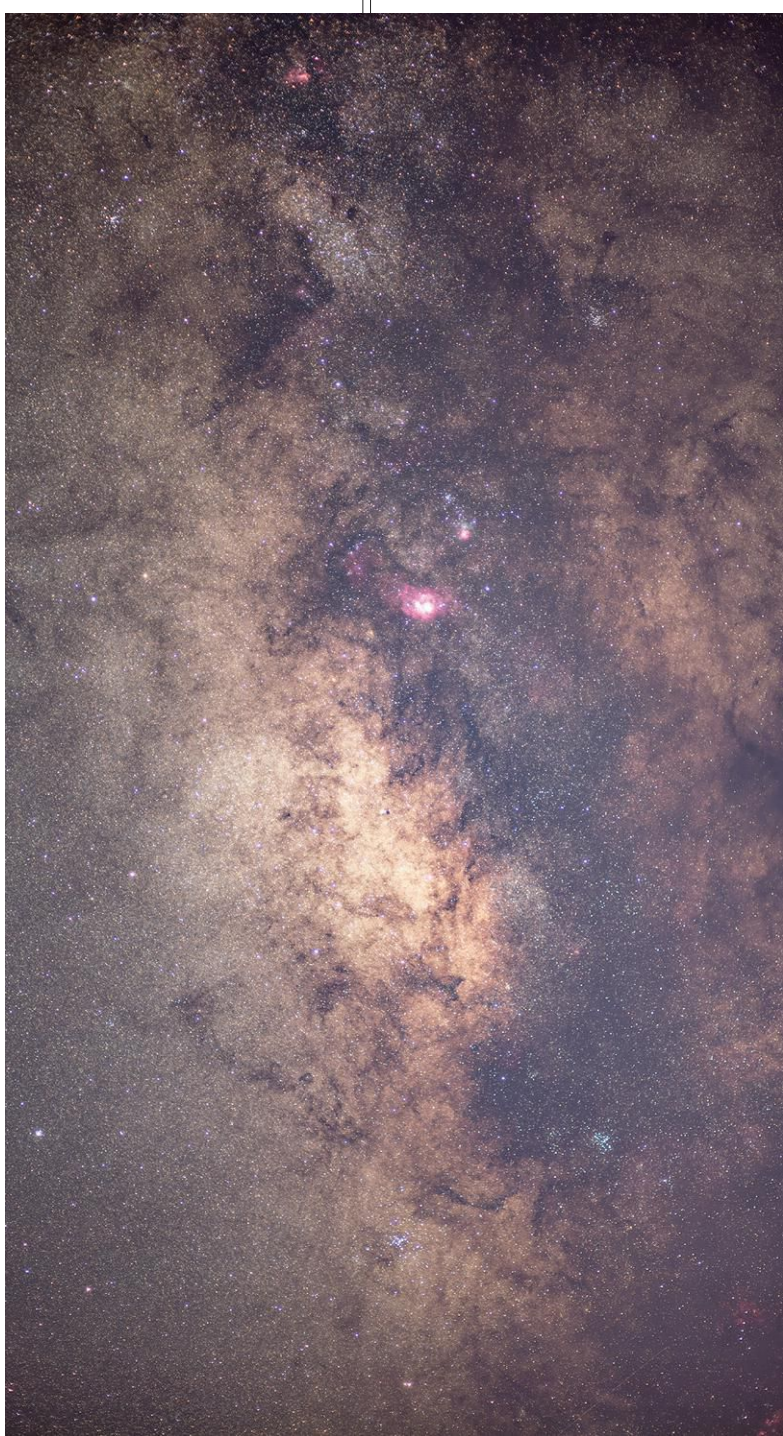


AINTNO OBJECTS

What's an AINTNO object? One where it could be said, "Ain't no way you'll observe that!" The AINTNO 100 is a tongue-in-cheek catalog of extremely challenging targets for visual observers originally compiled by amateur astronomers Larry Mitchell and Barbara Wilson in the 1990s. The acronym stands for Association of Invisible Nebulae and Things Nobody Observes.

One object on the list near the northern galactic bulge that would be really neat to observe — if at all possible — is the Sun glinting off of Voyager 1. The probe, launched in 1977, is currently in the center of a triangle formed by Alpha and Kappa (κ) Ophiuchus and Alpha Hercules.

Unfortunately, I'm pretty sure that if someone comes to you and shows you an image with one of the Voyager spacecraft in it, or tells you they've got it tracking in their scope, you should check them for sobriety. *—A.B.*



Hubble's SWEEPS (or Sagittarius Window Eclipsing Extrasolar Planet Search) looked for exoplanets in the galactic bulge as a precursor to the Kepler mission. It's a gloriously thick starry area to pan around with a ground-based telescope as well. ADRIAN BRADLEY

Astrophotography

A wonderful imaging target is NGC 6334, the Cat's Paw Nebula, 3° west of Shaula (Lambda Scorpii), the tip of the Scorpion's tail. The further north you live in the Northern Hemisphere, the less time you get to capture this object.

Drechsler 29 (Dr 29) is a planetary nebula in Aquila that was discovered very recently — in 2019 by Marcel Drechsler. It sits at R.A. 19h32.8m, Dec. 15°43.2'.

For a challenge, try to snag Sharpless 2–27, a large ionized region in Ophiuchus centered on Zeta (ζ) Ophiuchi, the bright base of the constellation. It will usually require longer exposures and image stacking to appear. Single exposures often miss this region, even in dark skies.

Finally, check out the SWEEPS (Sagittarius Window Eclipsing Extrasolar Planet Search) region, the site of a survey completed in 2004 by the Hubble Space Telescope which sought to find exoplanets transiting in front of their stars. This star field shows up in a lot of Milky Way landscape images that highlight details in the Large Sagittarius Star Cloud. It's a small region that is brighter than its surrounding area and is a couple of degrees from the galactic center.

Whatever your setup, spend some time checking out the treasures speckled around the galactic center — even when it's not officially Milky Way season!

Adrian Bradley *is an astrophotographer, amateur astronomer, and all-around night-sky enthusiast.*

Visible to the naked eye
Visible with binoculars
Visible with a telescope

THE SOLAR SYSTEM'S CHANGING LANDSCAPE AS IT APPEARS IN EARTH'S SKY.
BY MARTIN RATCLIFFE AND ALISTER LING



From our point of view, the Moon and the Pleiades (M45) often "miss" each other in the sky, as shown here. But we are now in a sequence of monthly Pleiades occultations, with one visible from the U.S. this month. ALAN DYER

FEBRUARY 2025

A Pleiades occultation

We're quickly losing sight of Saturn, but Venus, Jupiter, and Mars dominate the sky. Uranus and Neptune are easy binocular objects. Mars is still at its best, having reached opposition last month. Jupiter has many satellite transits visible in small telescopes. And early in the month, the Moon passes in front of the Pleiades, visible from the western U.S.

Saturn appears low in the southwest at dusk and drops quickly from view, setting within three hours of sunset on Feb. 1. It descends each consecutive day and is 8° high an hour after sunset on the 15th, glowing at magnitude 1.1. The rings are very narrow — this is your last glimpse of them before the ring-plane crossing next month, which will be hidden by the Sun. The angle of the rings drops from 2.8° to 1.3° during February and they become a difficult feature to observe due to low altitude and twilight.

Mercury reaches superior conjunction with the Sun on the 9th and isn't visible early in the month. The small planet comes up to meet Saturn on the 24th, when they stand side by side. Start looking 5° high in the western sky 30 minutes after sunset. Mercury is brighter, at magnitude –1.3, with Saturn 1.5° to its left. Binoculars are best to visually capture this scene. Magnitude –4.9 Venus stands 22° degrees above the pairing, guiding your eye down to the horizon and the two fainter planets. You only have 30 minutes or so to see them before they set. Saturn is lost from view soon after this as it heads for conjunction with the Sun.

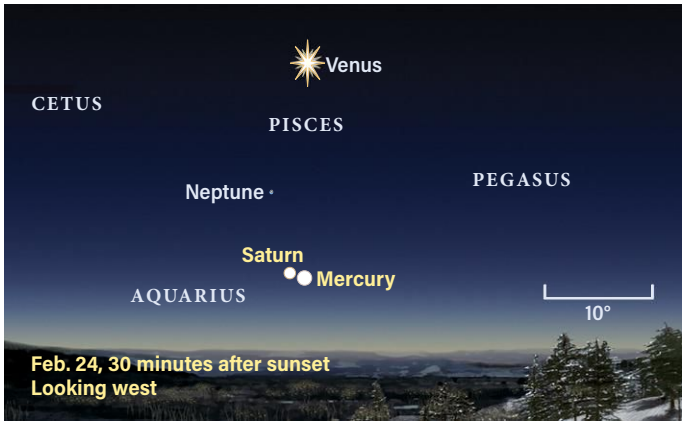
By contrast, Mercury climbs higher in the sky. On the 28th, a slender, one-day-old Moon greets the planet. The two stand 3° apart. Can you see the Moon? It's challenging to spot so soon after New. You'll need a western horizon free from obstructions as well as a clear sky with little haze. Through a telescope, Mercury reveals a 76-percent-lit disk spanning 6".

As Mercury and Saturn tussle for attention near the horizon, brilliant **Venus** stands well above them. On Feb. 1, a crescent Moon sits less than 3° from magnitude –4.7 Venus in a stunning evening display. Through a telescope, Venus reveals a 37-percent-lit disk, which thins during the month as its orbital path carries it closer to Earth. Viewing the disk is best in early twilight. Follow Venus throughout the month and watch its phase shrink to 15 percent, while its disk grows from 32" to 49".

On the 1st, Venus sets more than three hours after the Sun. By the 28th, it sets about 2.5 hours after the Sun. At 8 P.M. local time midmonth, it is 10° high in the western sky among the faint stars of Pisces the Fish.

Feb. 1 is also a great night to search for **Neptune**. Later in the evening, Neptune forms a perfect triangle with Venus and the

Planetary partners



Mercury and Saturn stand side by side in the early-evening sky near the end of February. Note that Neptune is not visible to the naked eye. ALL ILLUSTRATIONS: *ASTRONOMY*: ROEN KELLY

OBSERVING HIGHLIGHT

THE MOON occults **M45**
Feb. 5/6, with the entire event visible from the western third of the U.S.

Moon, with each point roughly 2° apart. Neptune is quite faint at magnitude 7.8, but there is a pair of stars (8th and 9th magnitude) near its location. Neptune has a distinctive bluish hue compared to the field stars.

Even 2.8 billion miles from Earth, Neptune shows a 2"-wide disk through a telescope under perfect seeing conditions.

Uranus lies near the border of Aries and Taurus, high in the southeast after sunset. You can find it 2.5° due south of 5th-magnitude 63 Arietis, easily spotted with binoculars 6° southwest of the Pleiades. Uranus shines at magnitude 5.7 through midmonth. Its 4"-wide disk is a challenge, but try under the best conditions with high magnification. Uranus is best viewed well before midnight.

Brilliant **Jupiter** is high in the sky at dusk, located 5° north of Aldebaran in Taurus the Bull. The distance between Jupiter and Earth is increasing this month, so the gas giant fades by 0.2 magnitude, ending February at magnitude –2.3.

Its retrograde path halts Feb. 4 and the planet resumes easterly motion across Taurus. A waxing gibbous Moon stands 5° north of Jupiter in the 6th, forming a line with Aldebaran.

Jupiter is observable well past midnight, setting after 3 A.M. local time on the 1st and by 1:30 A.M. on the 28th.

— *Continued on page 34*

RISING MOON | A long-lasting crescent

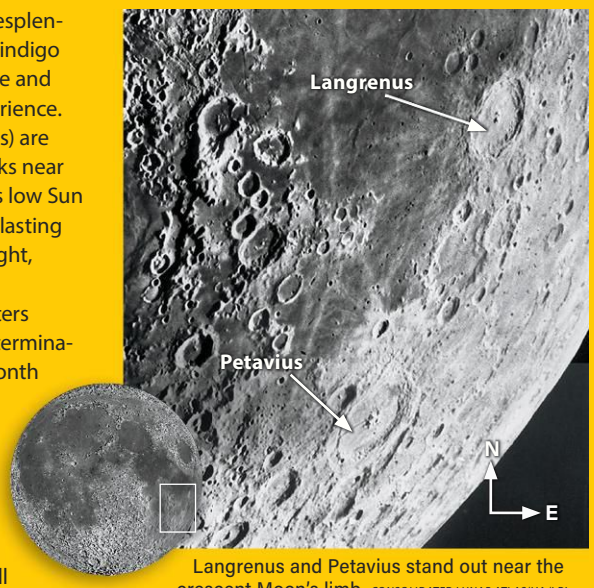
NORTHERN HEMISPHERE OBSERVERS of the crescent Moon love spring. Skywatchers have unparalleled views of the thin crescent resplendent with earthshine, perched in a deep indigo sky painted with a horizon of fiery orange and red. Binoculars add a jaw-dropping experience. Selenophiles (or lunatics, as friends call us) are wowed by the large crater walls and peaks near the limb, which cast long shadows at this low Sun angle. The enjoyment is sweet and long-lasting because the Moon sits high in early twilight, thanks to the steep angle of the ecliptic.

Next month on the 2nd, the large craters Langrenus and Petavius are right on the terminator, just catching the first rays, but this month on the 2nd, the Sun has reached the peaks and western walls. Eighty-mile-wide Langrenus is not as young as Copernicus, but its features are still relatively sharp. A couple of nice central mountains stand out from the surrounding slumped walls. In a few nights you will see its apron of debris, secondary craters, and ejecta rays more easily.

Petavius to the south is a bit bigger, a bit older, and sports extra features. Its rim is softer, telling of a longer life of bombardment. Its most interesting feature is a huge radial fracture emanating from its complex cluster of peaks. Look closely and you should also be able to pick up a large, curving crack closer to the rim. Both of these fractures were created when lava from below heaved up the floor and later subsided. Junior bakers see these effects in their pie crusts if they have not learned to vent the steam.

The next transformation takes place on the 14th, just after Full phase, when sunset arrives and the light has switched sides. Over the course of a few hours, the shadows of the central peaks get longer and eventually touch the crater rims.

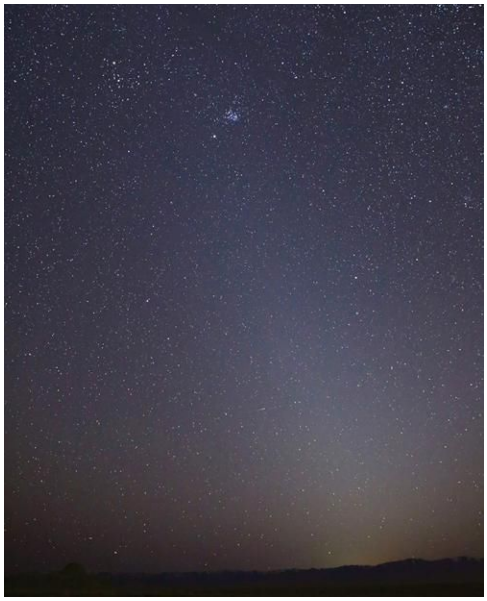
Langrenus and Petavius



Langrenus and Petavius stand out near the crescent Moon's limb. *CONSOLIDATED LUNAR ATLAS*/UA/LPL. INSET: NASA/GSFC/ASU

METEOR WATCH | A quiet month

Reaching up



FEBRUARY HAS NO major meteor showers. Sporadic meteors can be seen at any time, so it's worth keeping watch for the occasional bright streak while observing the wonders of the night sky.

As we approach the vernal equinox, the zodiacal light makes an evening appearance on moonless nights. The most favorable time is the second half of the month, when the Moon is in the morning sky. Pick a dark location with a clear view west. Right after dusk, as the sky darkens, watch for a cone-shaped glow, similar to the Milky Way. Whereas twilight is a low, diminishing glow to the west, the zodiacal light is a steeply angled cone aligned with the ecliptic in the east, extending up through Taurus. It lasts over an hour and is caused by sunlight reflecting off billions of meteoritic particles.

In spring, the zodiacal light appears in the evening sky as seen here, reaching up through Taurus to the Pleiades. NASA/BILL DUNFORD

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. February 1
9 P.M. February 15
8 P.M. February 28

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

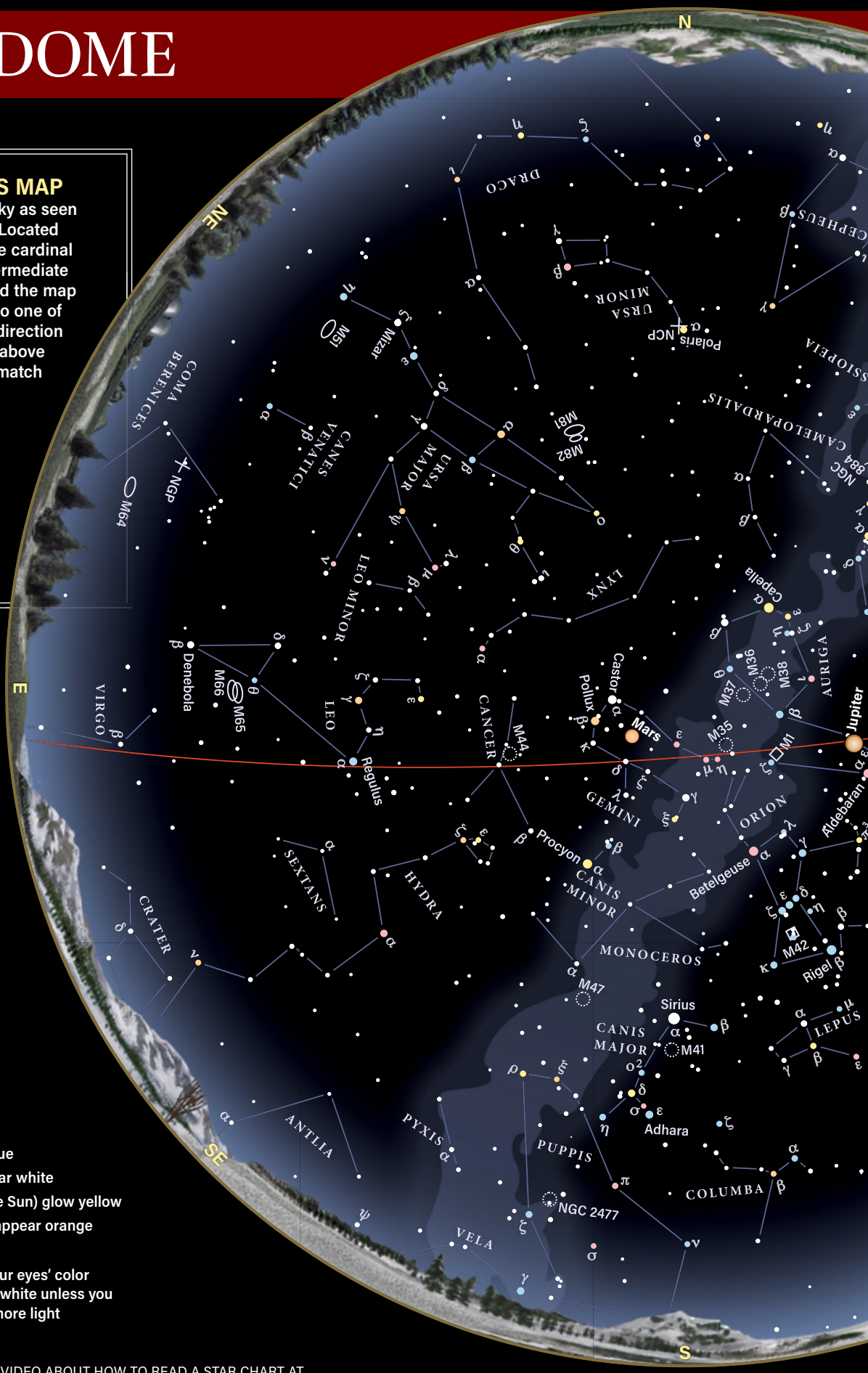
STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

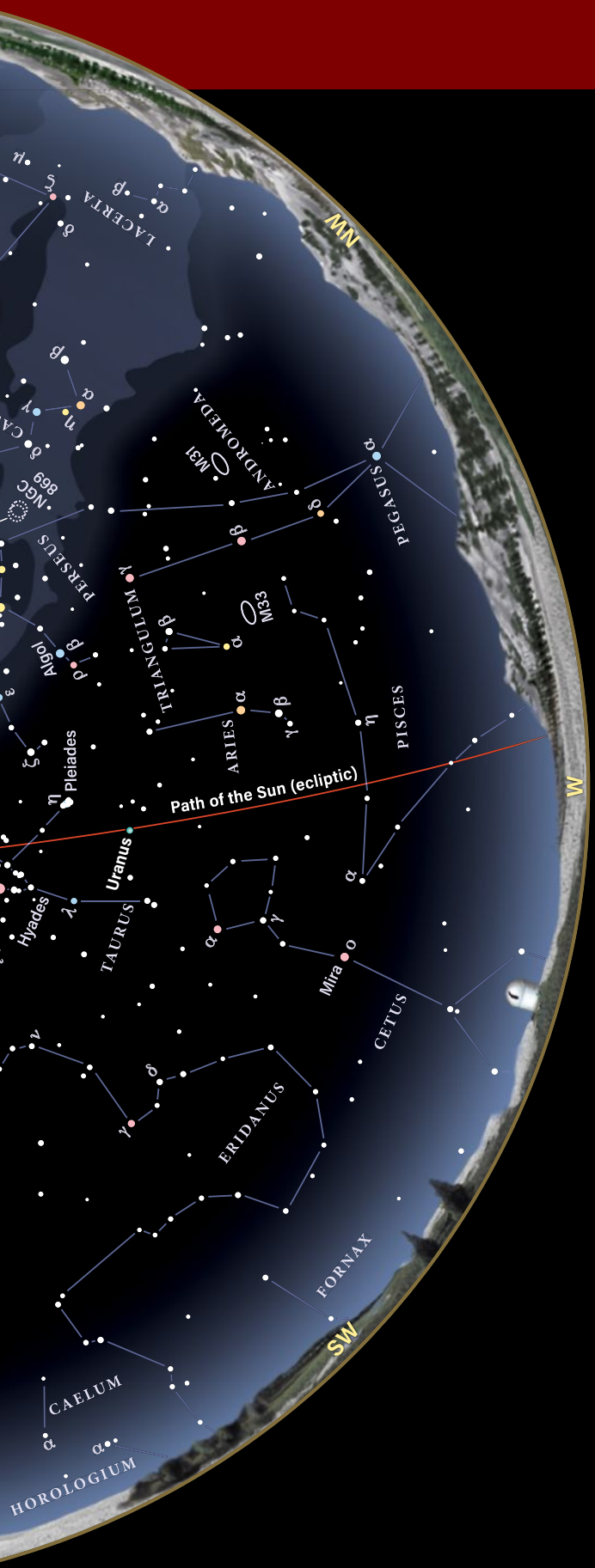
STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT **www.Astronomy.com/starchart.**



FEBRUARY 2025

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 The Moon passes 2° south of Venus, 3 P.M. EST

The Moon passes 1.4° north of Neptune, 6 P.M. EST

The Moon is at perigee (228,327 miles from Earth), 9:47 P.M. EST

3 Venus passes 4° north of Neptune, 3 P.M. EST

4 Jupiter is stationary, 8 A.M. EST

5 First Quarter Moon occurs at 3:02 A.M. EST

The Moon passes 5° north of Uranus, 4 P.M. EST

6 The Moon passes 5° north of Jupiter, 11 P.M. EST

9 Mercury is in superior conjunction, 7 A.M. EST

The Moon passes 0.8° north of Mars, 3 P.M. EST

12 Full Moon occurs at 8:53 A.M. EST

14 Dwarf planet Ceres is in conjunction with the Sun, 5 P.M. EST

Venus is at greatest brilliancy (magnitude –4.9), 6 P.M. EST

17 The Moon passes 0.3° south of Spica, 8 A.M. EST

The Moon is at apogee (251,582 miles from Earth), 8:10 P.M. EST

20 Last Quarter Moon occurs at 12:33 P.M. EST

21 The Moon passes 0.4° south of Antares, 4 A.M. EST

24 Mars is stationary, 5 A.M. EST

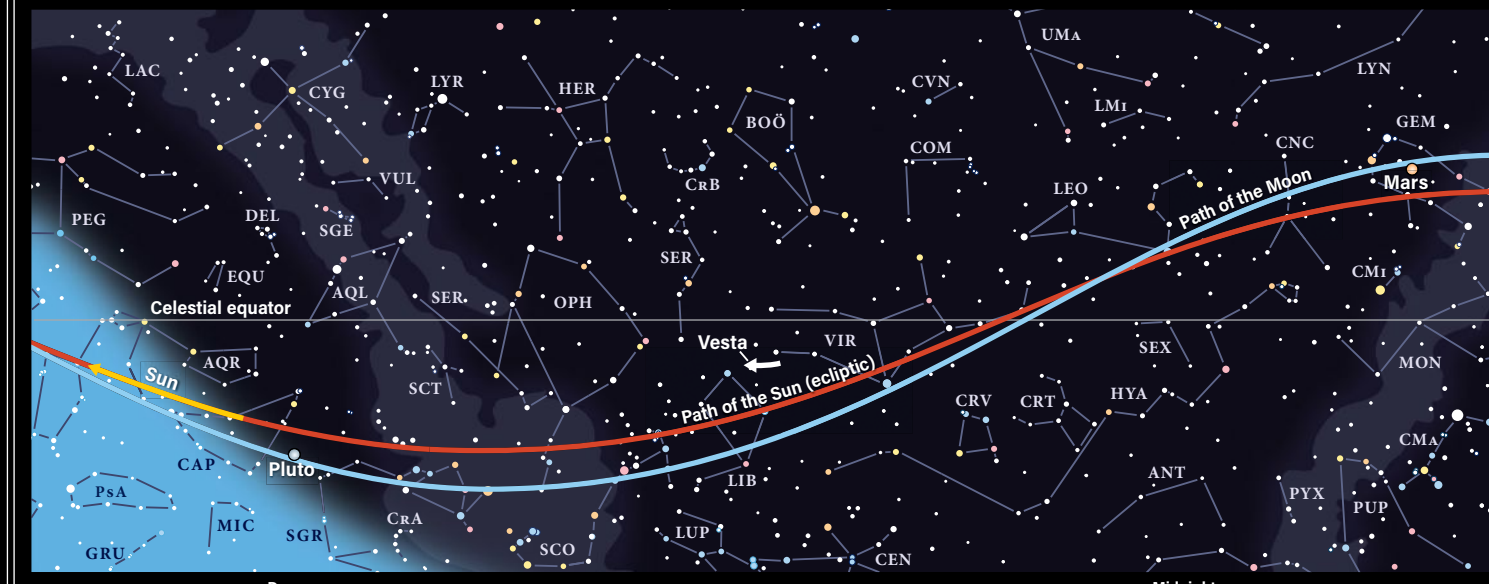
25 The Moon passes 1.0° south of Pluto, 5 A.M. EST

27 New Moon occurs at 7:45 P.M. EST

Venus is stationary, 10 P.M. EST

28 The Moon passes 0.4° south of Mercury, 11 P.M. EST

PATHS OF THE PLANETS



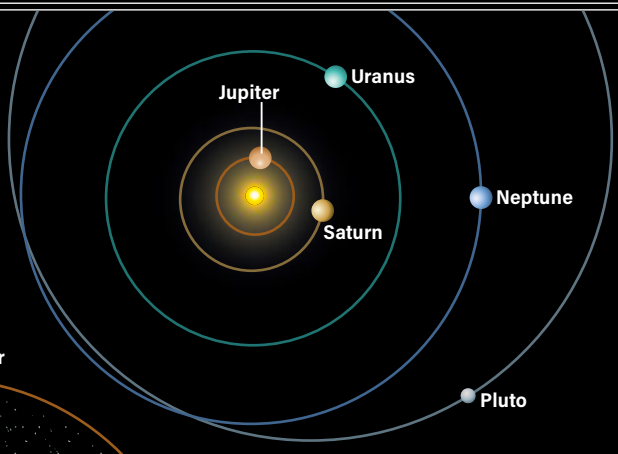
Moon phases

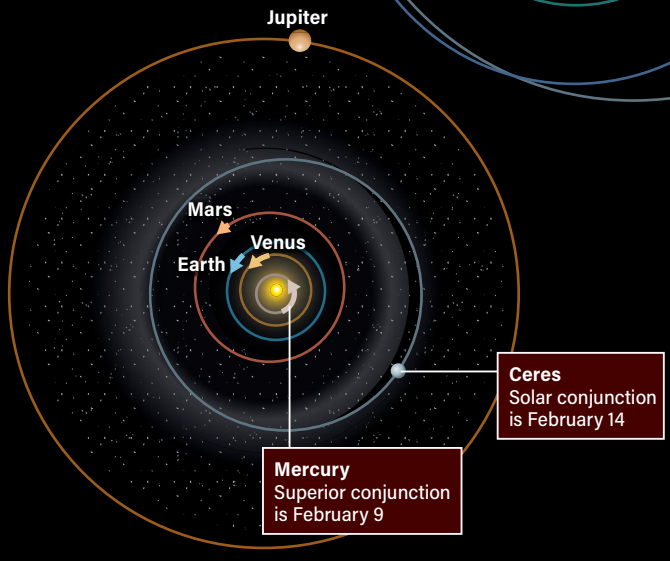
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

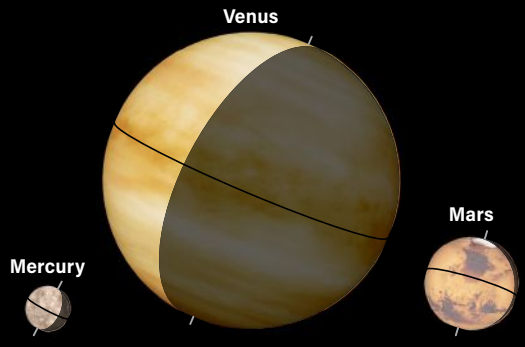


THE PLANETS IN THEIR ORBITS

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at midmonth from high above their orbits.



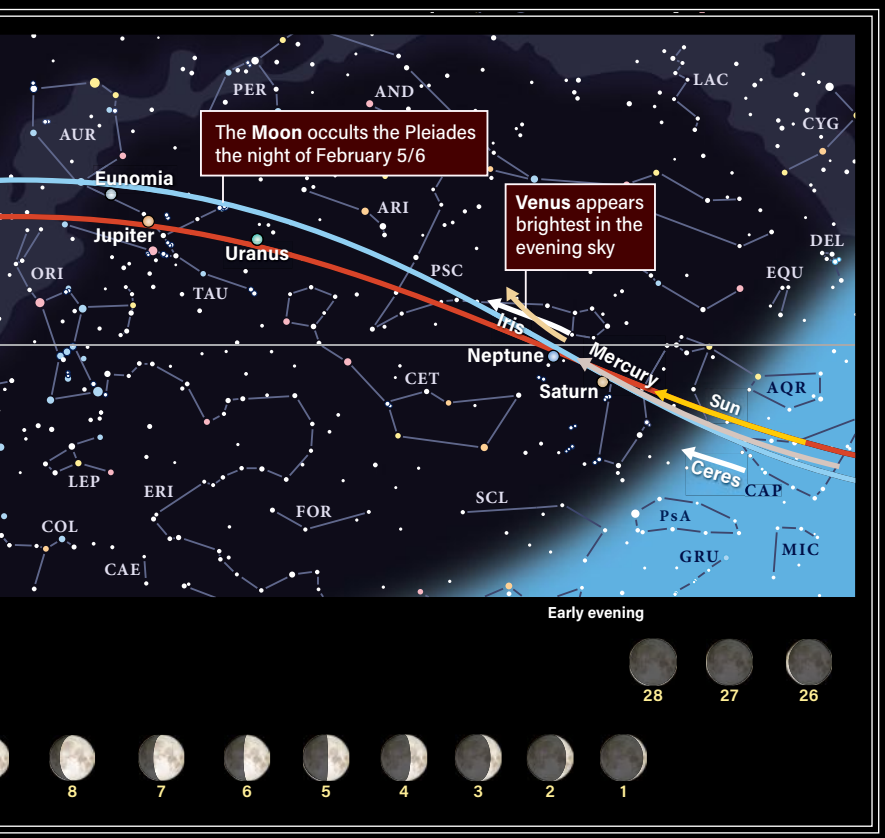




PLANETS	MERCURY	VENUS
Date	Feb. 28	Feb. 15
Magnitude	–1.1	–4.9
Angular size	5.9"	39.2"
Illumination	79%	27%
Distance (AU) from Earth	1.139	0.425
Distance (AU) from Sun	0.314	0.718
Right ascension (2000.0)	23h38.9m	0h16.8m
Declination (2000.0)	–2°15'	6°24'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

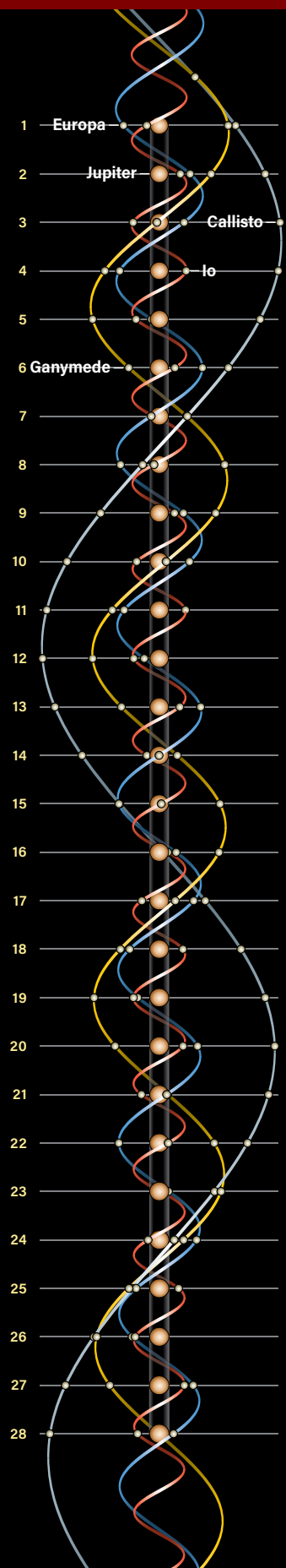
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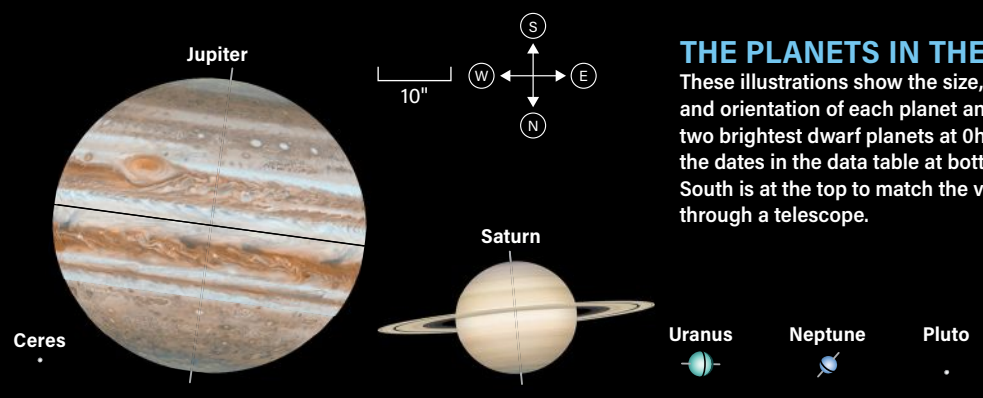




JUPITER'S MOONS

Dots display positions of Galilean satellites at 11 P.M. EST on the date shown. South is at the top to match the view through a telescope.



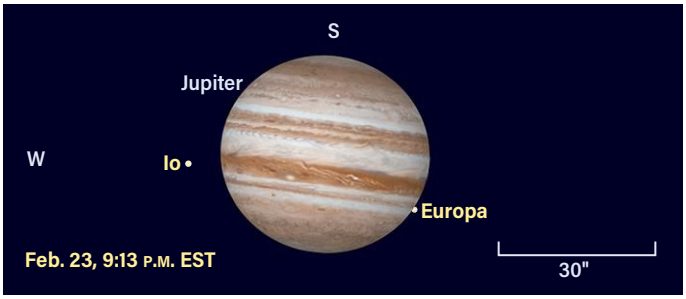


THE PLANETS IN THE SKY

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets at 0h UT for the dates in the data table at bottom. South is at the top to match the view through a telescope.

MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Feb. 15	Feb. 15	Feb. 15	Feb. 1	Feb. 15	Feb. 15	Feb. 15
−0.7	9.0	−2.4	1.1	5.7	7.8	15.2
12.3"	0.3"	41.5"	16.0"	3.6"	2.2"	0.1"
96%	100%	99%	100%	100%	100%	100%
0.759	3.961	4.753	10.411	19.576	30.727	36.100
1.648	2.984	5.098	9.621	19.546	29.893	35.202
7h16.8m	22h04.0m	4h38.5m	23h15.5m	3h22.7m	23h54.9m	20h20.9m
26°15'	−19°38'	21°40'	−6°53'	18°18'	−1°56'	−22°56'

Hide and seek



On the 23rd, you'll have only minutes to catch sight of Europa as it passes out from behind Jupiter and then into the planet's long shadow, moving eastward. Callisto and Ganymede lie to the east, outside this field of view.

Telescopic views are a delight, showing its dark equatorial belts, four Galilean moons, and occasionally the Great Red Spot. Scopes over 6 inches will reveal finer detail in Jupiter's dynamic atmosphere, particularly with steady moments of seeing.

Jupiter's disk spans 43" on Feb. 1 and drops to 40" by the end of the month. Its fast rotation (under 10 hours) enables you to see cloud motion within 10 to 15 minutes. Recording details, either on paper or high-speed video, will generate results to keep for posterity.

Io, Europa, Ganymede, and Callisto garner a lot of interest, particularly when they or their shadows transit the disk, or are eclipsed by Jupiter's great shadow, extending into space behind the planet.

Io and its shadow transit Feb. 1; Io exits by 8:54 P.M. EST, while its shadow leaves at 10:04 P.M. EST. It's Europa's turn on the 7th, with the moon transiting at nightfall across the western U.S. The shadow appears on the eastern limb around 9:35 P.M. EST, while Europa leaves the western limb less than 10 minutes later. By 12:10 A.M. EST, the shadow transit ends.

Io repeats its transit on the 8th, starting about 8:35 P.M. EST, followed by its shadow just over an hour later. Note how close the moon and its shadow are compared to Europa the previous night — Io has a smaller orbit. Io leaves the disk at 10:45 P.M. EST and its shadow follows at midnight EST.

The moons repeat Feb. 14/15 (Europa) and 15/16 (Io). Europa's Feb. 14 transit begins at 8:40 P.M. EST, its shadow following at 12:10 A.M. EST. The moon departs the disk minutes later at 12:13 A.M. EST. On the 15th, Io's transit begins at 10:26 P.M. EST and the shadow transit begins at 11:43 P.M. EST. Io's egress is 12:38 A.M. EST, followed by its shadow one hour and 15 minutes later.

On the 21st, Ganymede reappears from behind Jupiter at 8:32 P.M. EST, a process that takes a few minutes. This occurs in twilight across the Mountain time zone and daylight on the West Coast, but the eastern half of the U.S. gets a fine view. Later in the evening, Ganymede enters Jupiter's extended shadow 28" off the northeastern limb. The moon begins fading shortly after 11:25 P.M. EST and takes more than five minutes to disappear. How long can you see it?

Callisto is far enough from Jupiter that, from our perspective, it misses the planet entirely. Spot Callisto north of Jupiter in the early evening of Feb. 16.

The 23rd brings a triple event. Io is approaching the western limb around 9 P.M. EST, but turn your attention to the northeastern limb, where Europa reappears from behind Jupiter, but only for a couple of minutes before it enters Jupiter's shadow. It should be visible between 9:11 P.M. and 9:15 P.M. EST, then fade from view. Io is occulted by the western limb at 9:37 P.M. EST. At 11:54 P.M. EST, Europa reappears from eclipse

WHEN TO VIEW THE PLANETS

EVENING SKY
Mercury (west)
Venus (west)
Mars (east)
Jupiter (south)
Saturn (west)
Uranus (southwest)
Neptune (west)

MIDNIGHT
Mars (west)
Jupiter (west)
Uranus (west)

MORNING SKY
Mars (northwest)

COMET SEARCH | Drought may offer a surprise

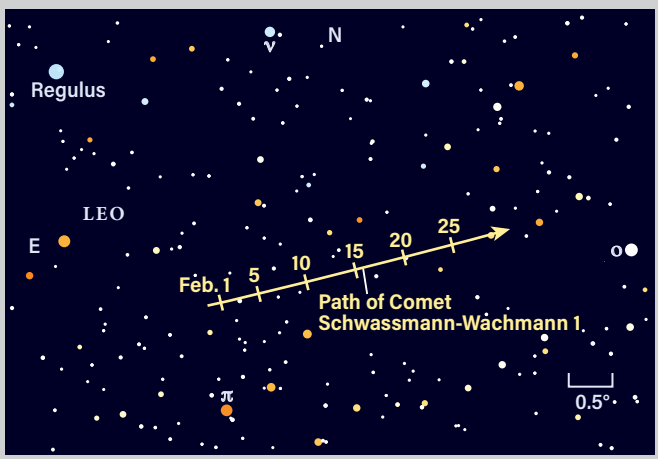
AN ABSENCE OF BRIGHT COMETS leaves us hoping for an outburst from an unruly Centaur or the fresh delivery of an inbound primordial newbie.

Centaurs such as 29P/Schwassmann-Wachmann orbit between Jupiter and Neptune, having migrated in from the Kuiper Belt. This enigmatic object erupts semi-regularly, causing a one-day jump in brightness from a feeble 15th magnitude to 10.5 — not tough for an 8-inch scope under dark skies and within range of an imager from the suburbs. Look for it south of Regulus this winter.

Calibrate your mind by starting on 9th-magnitude NGC 2903 in Leo's Sickle; this spiral was a smidge too faint for Messier. Follow up with nearby NGC 2916 (magnitude 12.6); try powers of 150x or more. When you swing over to the comet's position, you'll have an outburst if it's brighter than NGC 2916.

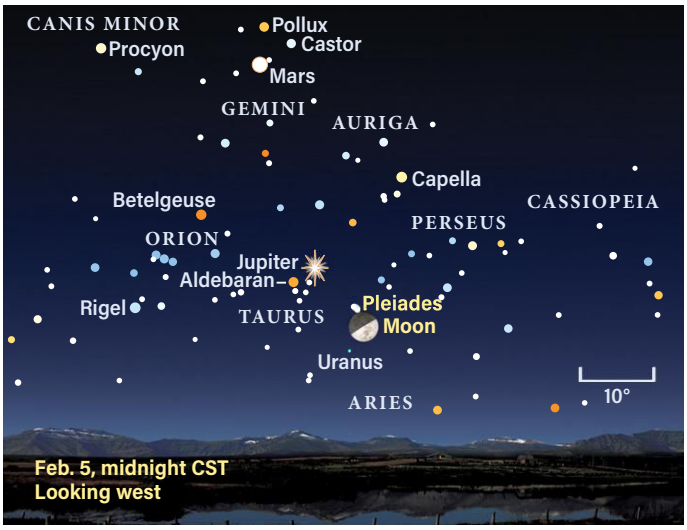
Sometimes a small comet comes out of the deep and approaches Earth closely enough to shine at 7th to 8th magnitude within six months of discovery. Check Astronomy.com for announcements and finder charts.

Comet 29P/Schwassmann-Wachmann



Technically a small icy body, 29P/Schwassmann-Wachmann (Schwassmann-Wachmann 1) is thought to be about 10 times bigger than Halley's comet. Perhaps it will surprise us with an outburst.

Passing through



On Feb. 5/6, the Moon occults the Pleiades (M45), starting shortly after 1 A.M. CST. The western third of the U.S. will be able to see the whole event.

within Jupiter's shadow, some 36" from the northeastern limb.

The night of Feb. 3/4, Ganymede's huge shadow takes 10 minutes to fully appear on the disk, beginning around 1:30 A.M. EST (on Feb. 4 in the eastern half of the U.S.). Ganymede itself is nearly 30" from the western limb. Watch the elongated shadow move slowly across Jupiter's cloud tops. The shadow finally starts its exit around 3:50 A.M. EST.

Mars forms an elegant triangle with Castor and Pollux, Gemini's brightest stars, on Feb. 1. Shining at magnitude –1.1, Mars stands 4.2° southwest of 1st-magnitude Pollux and 1.8° southwest of 4th-magnitude Upsilon (υ) Geminorum.

Mars is visible all night, climbing above 60° altitude by 9 P.M. local time. Mars continues along its retrograde path into central Gemini until late February. On the 24th, it reverses course and resumes an easterly trek toward Pollux.

Mars' diameter is 14" when February opens but diminishes to 11" by the end of the month.

At 9 P.M. local time from the central U.S. (look an hour later in the east and an hour or two earlier farther west), Mars shows off Mare Cimmerium in February's the first week. Gradually, at the same time each night, Olympus Mons appears on the western limb. From Feb. 7 to 13, Olympus Mons and the Tharsis ridge move more centrally on the disk.

In mid-February, Valles Marineris is visible. Dark, spidery Solis Lacus is central from Feb. 18 to 20, as Sinus Meridiani appears on the western limb. By the 24th, Sinus Meridiani is central, and in the remaining days of the month, Syrtis Major appears progressively more prominent on the western limb.

Night owls are in for a treat Feb. 5/6. The First Quarter Moon will pass in front of the stunning Pleiades star cluster (M45), hiding each star in turn for a period of an hour or so.

The entire event is observable from the western third of the continental U.S., with the Moon setting in the middle of the cluster from the eastern U.S. The event is also visible from countries with a similar longitude.

From Kansas City, Electra is occulted at 1:21 A.M. CST with the Moon 10° high in the west. Observers with a clear horizon may see Merope occulted at 1:57 A.M. CST, with the Moon just over 4° high. Those farther west see more occultations, including Alcyone and Atlas. Look for local timing on the International Occultation Timing Association's webpage for bright star occultations (www.lunar-occultations.com/bobgraze/index.html), or check the Royal Astronomical Society of Canada's 2025 *Observer's Handbook*.

The Pleiades are occulted monthly in a series that began Sept. 5, 2023, and will continue until July 7, 2029. Some events are not visible from North America or occur in daylight.

Martin Ratcliffe *is a planetarium professional with Evans & Sutherland and enjoys observing from Salt Lake City.* **Alister Ling**, *who lives in Edmonton, Alberta, is a longtime watcher of the skies.*

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LOCATING ASTEROIDS
Path through the stellar forest

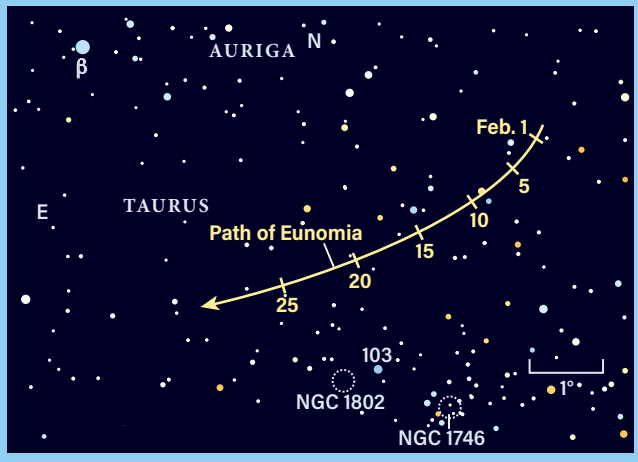
YEARS AGO, I was startled by the sudden disappearance of stars as I searched for cluster NGC 1746 in Taurus. Main-belt asteroid 15 Eunomia beckons me to return to the wonderful lanes of interstellar dust in this rich part of the winter Milky Way.

Suburban observers can start at magnitude 5.5 103 Tauri or 6th-magnitude NGC 1746. Slowly shift your scope 1° north and all the 7th- to 8th-magnitude field stars drop from sight. Magnitude 9.6 Eunomia becomes a standout.

Because the 170-mile-wide space rock is a slow mover, it is best to make a sketch of the field with four to six dots, then come back another night to identify the one that is missing. Eunomia passes good background patterns for this from Feb. 7–11, 20–21, and 27–28.

The ideal view is a 3°-wide field from a dark site, but sweeping a scope manually from Beta (β) Tau toward Aldebaran is an eye-opening experience. If E.E. Barnard had imaged this region, there would be many objects bearing his name, but Beverly Lynds picked up where he left off, gifting us plenty of Lynds Dark Nebulae (LDN) to "not see."

Stars and voids



Eunomia passes near the 6th-magnitude star cluster NGC 1746 this month, which is the parent of several smaller groups and associations.



NEW HORIZONS measures how dark the universe can get

> The results are in line with theory — but the key was understanding how dusty the galaxy is.
>
> BY RANDALL HYMAN

AS BLACK AS SPACE MAY SEEM, even the darkest corner of the universe gets light. Measuring that tiny glimmer — called the cosmic optical background (COB) — sheds light on the energy balance of the entire universe, one of cosmology's holy grails.

With recent data gathered by the New Horizons spacecraft, now 57 times farther away from the Sun than Earth, astronomers believe they have finally quantified the COB. It is none other than the cumulative light of the hundreds of billions of galaxies formed since time began.

If you could capture this light coming from all directions in deepest space and place it in a bottle, it would glow no brighter than a firefly 3 feet (1 meter) away.

This is in line with what theory predicts, but it is a great relief to the team of astronomers whose prior study suggested a mysterious light source no one had considered. Compared to the estimated sum of all light generated by galaxies, their 2021 study was off by a factor of two.

"In our previous paper," says lead author Marc Postman of the Space Telescope Science Institute in Baltimore, "we found there was as much light we couldn't account for as light we could measure. The real 'gotcha' was that we simply weren't as familiar with the distribution of dust in the Milky Way as we should have been."

The new work was published Aug. 28 of last year in *The Astrophysical Journal*.

How dark can space get?

Measuring how dark space is sounds simple, but to do so accurately is quite tricky. For starters, it can't be done from the inner solar system because of a phenomenon familiar to stargazers: the zodiacal light. On Earth, this appears as a triangle of light after sunset or before sunrise, caused by a cloud of dust particles that orbit the Sun and scatter its light.

To escape this light, researchers turned to New Horizons, the spacecraft that made the first-ever flyby of Pluto in 2015. Though its instruments weren't designed to measure the COB, researchers realized they could take advantage of the craft's location, far out in the Kuiper Belt, which is effectively immune to zodiacal light.

LEFT: Galactic cirrus clouds — like these, which comprise the object Mandel-Wilson 1 (MW1) — are wispy tendrils of gas that lie outside the plane of our galaxy. They are lit not by a single star, but the overall glow of the Milky Way. Understanding the extent of galactic cirrus proved critical to an accurate measurement of the cosmic optical background. JOSH JONES

The team published initial findings in 2021, using observations from New Horizons' archives where the craft happened to be aiming its camera out of the Milky Way's disk, toward its poles. By choosing these fields, the team intended to avoid dust in the galaxy. But their analysis showed that the COB appeared brighter than expected — suggesting some unexplained cosmic component.

To investigate, the team then took new observations with New Horizons' Long Range Reconnaissance Imager (LORRI) to create a more comprehensive survey of the COB that eventually included 23 fields of view. The team had to take care to position LORRI away from the Sun, the luminous inner disk of the Milky Way, and bright nearby stars.

Crucially, this broader survey allowed the team to make use of a map of galactic dust made by the European Space Agency's Planck mission. Although those data were taken in far-infrared wavelengths, the team could use them to estimate how those dust clouds would scatter optical light and correct for it in the COB images. This approach was not available to the team back in 2021, when they had less data to work from.

The results showed that the team had originally underestimated the amount of light scattered by dust in the Milky Way — and overestimated the intensity of the COB. The previously unexplained brightness "was actually real galactic dust that happened to be at very high galactic latitude," says Postman.

Infrared cirrus clouds are a major source of this light. These dusty, filamentary galactic structures emit in the far-infrared wavelength range, but also scatter optical light. "It's a very apt name, because it's like cirrus clouds in our atmosphere," says co-author Tod Lauer of the National Optical Infrared Astronomy Research Laboratory in Tucson, Arizona.

While cirrus clouds on Earth scatter sunlight, galactic cirrus clouds scatter light from stars in our galaxy — even when the source is nowhere near the clouds themselves. Because these high-latitude clouds lie outside the Milky Way and reflect light from the overall glow of the galaxy, amateur astronomers often refer to them as integrated flux nebulae.

Now that the contribution of galactic cirrus has been accounted for, "I think we are the first ones that can say it's pretty clear that it's just galaxies" that produce the COB, says Lauer.

Their measurement of the COB is still slightly more than the estimated total of all galactic light. That leaves some wiggle room that could potentially accommodate future light source discoveries. But the simplest explanation, as Postman puts it, is that "what we see when we look at the cosmic optical background is the sum of all light that is produced from the history of star formation over the entire universe."

The rest of the spectrum

Beyond optical light, astronomers are also keen to measure the rest of the electromagnetic (EM) spectrum in order to understand the complete energy budget of the universe. Adding up radio, infrared, optical, ultraviolet, and X-rays is the surest way.

The earliest such discovery was the cosmic microwave background (CMB) — and it was a complete accident. In 1965, two radio astronomers in New Jersey were tuning a microwave antenna when they picked up constant excess noise radiating from all directions.

Arno Penzias and Robert Wilson had stumbled upon something big — the light that emerged before there were any galaxies, stars, or black holes. Postman calls it the cooling embers of the Big Bang.

For 50 years, astronomers unsuccessfully tried to measure its optical equivalent. It took New Horizons — a little spacecraft with an 8-inch telescope and a small black-and-white camera — moving into the outer reaches of our solar system to finally get the answer.

"It was a learning process," says Postman, "but, in the end, it resulted in the most significant detection of the cosmic optical background that's ever been made."

Randall Hyman *is a science writer whose work has been featured in numerous publications, including* Nature, Science, *and* Smithsonian.

LEFT: The New Horizons spacecraft flew by Pluto in 2015. More recently, a team of astronomers has used its instruments to measure the cosmic optical background, hoping to calculate the overall brightness of the universe. NASA, APL, SWRI, SERGE BRUNIER (ESO), MARC POSTMAN (STSCI), DAN DURDA

RIGHT: The zodiacal light is captured over the La Silla Observatory in Chile in September 2009. ESO/Y. BELETSKY







Oberwerk's BT-127XL-SD binoculars come with a foam-lined carry case and a pair of 46x eyepieces. Compatible Oberwerk tripods and eyepieces (30x and 93x) can be bought separately. OBERWERK

ENTER THE BIG BINOCULAR UNIVERSE

You can call Oberwerk's BT–127XL–SD binoculars, but it's really a pair of 5-inch refractors. BY TONY HALLAS

I HAVE ALWAYS **ENJOYED** looking at the sky on a clear night through binoculars. Seeing through individual optics for each eye creates a feeling of being in space. It's different than looking through a telescope. Aesthetically, I find it much more pleasing.

Most binoculars, unfortunately, just don't collect enough light for real deep-sky viewing. But what if you could find binoculars big enough to qualify as small telescopes? Wouldn't that be like having a telescope for each eye?

If you think so, get ready for the Oberwerk BT–127XL–SD apochromatic triplet binoculars.

First impressions

These binoculars have been created with no compromise. The triplet objectives are made with the same glass (both FCD 100 and FK-61) used in expensive refractors and are fully multicoated. The prisms are huge, allowing full coverage from any 1¼" eyepiece. (Yes, you can change out the eyepieces in seconds. More on this later.) The interpupillary distance, which is the distance between human eyes, is adjustable from 57 to 80 millimeters. I've had no problems with the binoculars as various people adjusted the BT-127XL-SD to their eye width. The binoculars come with sliding dew shields and metal covers for the objectives. They're also finished in iridescent Luna Pearl White paint with an anodized trim. Besides being beautiful to look

through, they're also beautiful to look at.

The prisms are set at 45°, the best compromise for viewing objects at both low and high altitudes. I found it useful to have a tripod that has an elevator column so that you can smoothly adjust the eyepiece position for those who are not the same height.

You can purchase the binoculars with a variety of support structures. The classic is a wooden tripod with an elevation bar and swivel that the binoculars bolt to. The more advanced system I used is one of Oberwerk's heads that sits on a Manfrotto 161MK2B tripod, which has a crank-operated elevator that can raise the binoculars to nearly 9 feet (2.74 meters). It's a solid little mount that holds the binoculars with no vibration.

Even with two 5-inch triplet objectives and massive prisms, the magnesium alloy construction keeps the weight of these binoculars at just 24 pounds (10.9 kilograms). I have no trouble setting them up by myself.

Every BT-127XL-SD is tested and collimated prior to shipping with optics certified to a magnification of 163x. The binoculars come with a sturdy case with wheels on one end, making transportation to your favorite dark site effortless. Setting up and taking down the entire system takes only a few minutes each. Oberwerk also provides a limited three-year warranty.

Eyes wide open

Let's talk about the eyepieces and visual experience offered by these 5-inch binoculars, which come with Oberwerk 14mm (46x) 70° apparent field of view eyepieces. You can also buy 22mm (30x) and 7mm (93x) eyepieces to create a versatile set. The company sells each pair for $319.95. The eyepieces lock in place with a thin ring that sits on top of the much deeper focusing ring. You focus each eyepiece individually.

These binoculars crave dark and transparent skies. Trips through Sagittarius and Scorpius under these conditions have to be seen to be believed. Everything looks 3D. When you look with both eyes, brighter objects fool the mind into thinking that they are in front of dimmer detail. The apochromatic objectives are completely color free. I have looked for, but never found, any color fringing. And just as importantly, stars remained mere pinpricks through all of my eyepieces.

The BT-127XL-SD allows you to take a journey through star clouds and galaxies. Indeed, you can see galaxies in these — just as well and just as many as you would with any high-quality 5-inch refractor. You can see all of the Andromeda Galaxy (M31) within the field, bright and floating in the depths of space; I found the offered view unique. Changing eyepieces will certainly change the magnification, but will it provide more detail? It depends on the object really. Remember, each lens is only 5 inches of aperture, so there are limits.

The bottom line, then, is that the point of these binoculars isn't to see the closest, most detailed view of a celestial object, but rather to see a unique view using both eyes at once. Which brings up an important fact: Using both eyes eliminates eye fatigue. I have spent many years looking through telescopes with apertures as large as 24 inches with only one eye. After a while spent staring at an object, my eye got tired; the more I looked, the less I saw. With both eyes, I can look as long as I want. And in this case, the more you look, the more you see.

Finally, the tripod, mount, and binoculars are made in such a way that they can be transported to almost anywhere on the planet. Think of your most exotic observing location. Hawaii? Chile? Africa? There's a good chance the BT-127XL-SD can be there with you.

In short, Oberwerk has created something that dreams are made of: binoculars with 5-inch apochromatic objectives in a relatively lightweight, attractive body. Everything about these binoculars reflects fine workmanship. They are compact enough to go just about anywhere you go and allow views that will leave you happy. I recommend the Manfrotto tripod with the elevator column. Everything sets up in just minutes. For the budget-conscious, Oberwerk's eyepieces, both the pair that come with the binoculars and the ones the company offers for purchase, are an excellent choice. Once you have the BT-127XL-SD set up at a star party, you might find yourself the center of attention. There is something irresistible about large binoculars.



The main feature of the BT-127XL-SD is the pair of 5-inch apochromatic lenses, which are among the largest available for binoculars. OBERWERK

PRODUCT INFORMATION

Oberwerk BT-127XL-SD
Type: Apochromatic binoculars
Aperture: 5 inches
Focal length: 650mm
Eye relief: 15mm
Field of view: 1.52° (at 46x)
Weight: 24.5 pounds (11.1 kg)
Price: $5,995
Contact: Oberwerk
3880 Kettering Blvd.
Dayton, OH 45439
937.640.1040

Tony Hallas *is one of the world's best astroimagers and a lover of fine equipment.*

40 COSMIC QUESTIONS ANSWERED

Be the smartest observer at the star party. BY MICHAEL E. BAKICH

There are thousands upon thousands of questions related to the topic of astronomy, from the basics of the science to the complexities of the distant cosmos. Here are just 40 such questions that we as astronomers — professional and amateur — hear. I hope their answers help you explain some of these concepts to family, friends, or visitors at star parties.

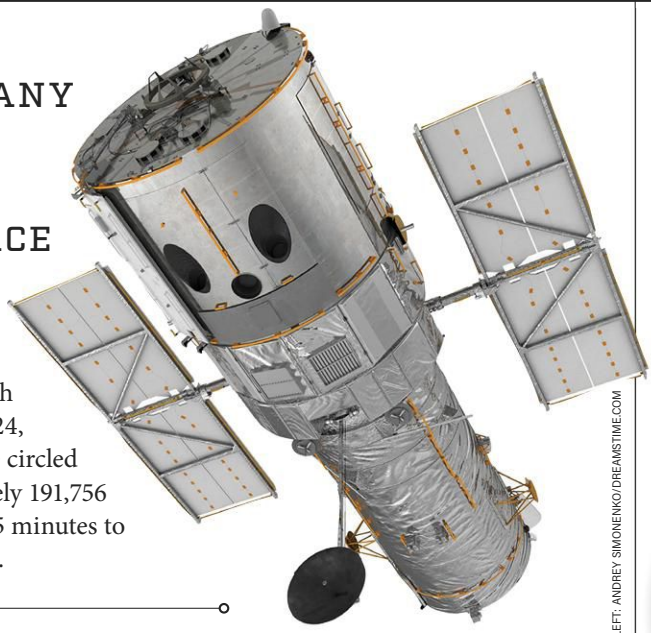
1 IS PLUTO A PLANET?

Not according to the International Astronomical Union (IAU), which demoted Pluto to dwarf planet status in 2006 after setting forth several criteria for planethood that it does not meet. This change remains controversial.



BELOW: NASA/JHUAPL/SWRI LEFT: JAYSI/DREAMSTIME.COM

2 HOW MANY ORBITS HAS THE HUBBLE SPACE TELESCOPE MADE?



As of its upcoming 35th anniversary, on April 24, 2025, Hubble will have circled our world approximately 191,756 times. It takes about 95 minutes to complete a single orbit.

3 HOW MUCH LARGER IS EARTH THAN THE MOON?

Our planet's diameter is 3⅔ as large as the Moon's. In other words, the Moon's diameter is 27.3 percent of Earth's. However, if we were to compare their volumes, Earth's is 50 times larger than the Moon's, so the Moon's volume is just 2 percent that of Earth.

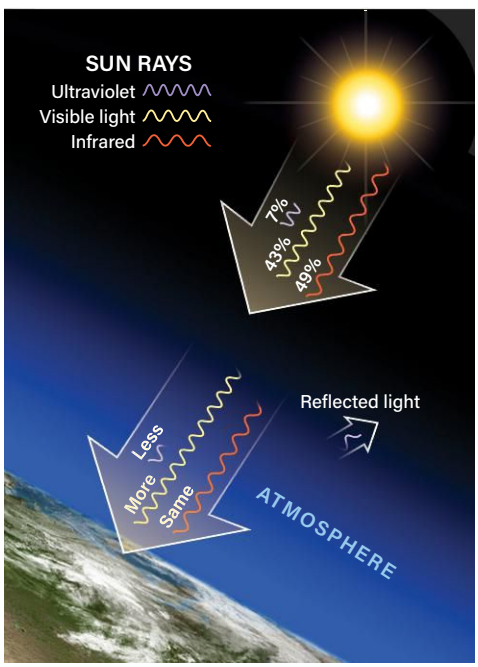


RIGHT: *ASTRONOMY:* ROEN KELLY; ABOVE LEFT: ANDREY SIMONENKO/DREAMSTIME.COM

4 HOW MANY CONSTELLATIONS DO THE MOON AND PLANETS PASS THROUGH?

In addition to the 12 zodiacal constellations, the Moon can appear in front of stars in Auriga, Cetus, Corvus, Ophiuchus, Orion, and Sextans. And in addition to those 18, the planets can appear in six more: Canis Minor, Crater, Hydra, Pegasus, Scutum, and Serpens.

5 HOW MUCH OF SUNLIGHT IS LIGHT?



ASTRONOMY: ROEN KELLY

What we call "sunlight" is actually a mixture of visible light, infrared radiation (heat), and ultraviolet radiation. When light leaves the Sun, the mixture is about 43 percent visible, 49 percent infrared, and 7 percent ultraviolet. But after the sunlight interacts with our atmosphere, which reflects some and absorbs some, what reaches the surface has a larger percentage of visible light. The amount of infrared stays roughly the same, while the amount of ultraviolet light decreases slightly.

6 ON AVERAGE, HOW MAY METEORS CAN YOU SEE?

For this answer, we're considering sporadic meteors — those not associated with any meteor shower. The hourly rate of sporadic meteors varies throughout the year. The rate is lowest in March, with about two to four meteors per hour, and rises to four to eight per hour in September. The rate also rises based on the time of night. These numbers are for early evenings. But if you observe in the hour before dawn, double them.

7 WHAT DOES $E=MC^2$ MEAN?

This is possibly the world's most famous formula. Albert Einstein used it to explain how stars produce energy. In the equation, E stands for energy, m is for mass, and c is the speed of light. That's already a large number, so it becomes colossal when you square it. Thus, nuclear fusion in stars converts tiny amounts of mass into huge amounts of energy.



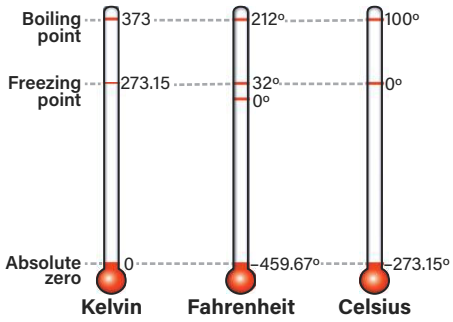
8 WHICH PLANET IS HOTTEST?

Although Venus lies 90 percent farther from the Sun than Mercury, Venus is the hottest planet in our solar system. The reason is the thick layer of carbon dioxide clouds, which create a planet-wide greenhouse effect. Venus' surface temperature is an astounding 867 degrees Fahrenheit (464 degrees Celsius) — hot enough to melt both tin and lead.

ABOVE: NASA. RIGHT AND BELOW: *ASTRONOMY*: ROEN KELLY (2)

10 WHAT IS ABSOLUTE ZERO?

It is the coldest temperature possible. It's 0 on the Kelvin scale, –459.67 degrees on the Fahrenheit scale, and –273.15 degrees on the Celsius scale. In 2021, a research team set the record for the coldest temperature achieved: 38 picokelvins (0.000000000038 K). For reference, the background temperature of the universe is approximately 2.7 K.



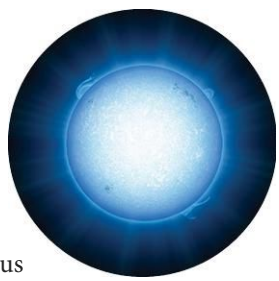


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11 WHY IS HALLEY'S COMET FAMOUS?

The main reason is that it was the first comet whose return was predicted. In 1705, British astronomer Edmond Halley declared that the comets that appeared in 1531, 1607, and 1682 were appearances of the same comet. He further predicted that it would return in 1758, which it did. Another reason Halley's Comet is famous is because it holds the title as the most frequently seen comet — it's been seen a total of 30 times throughout history.

9 IS THE NORTH STAR THE BRIGHTEST STAR?



No, the North Star, also known as Polaris and Alpha (α) Ursae Minoris, comes in as the 46th brightest (with a magnitude of 1.97) on the IAU's list of named stars as of Jan. 1, 2021. It is a variable star, though, so sometimes it can rise to 39th brightest and at other times fall to 62nd. The brightest star in the sky, Sirius (Alpha Canis Majoris), is visible from both hemispheres.

12 WHICH NAKED-EYE STAR IS THE BRIGHTEST?

You might want to say the Sun. But that's just because of proximity. If all stars visible to just our eyes were placed at the same distance (which astronomers have set at 32.6 light-years), the brightest would be Eta (η) Carinae, a variable star that usually glows around magnitude 4.5. It would shine at magnitude –8.6, some 230,000 times as bright as our Sun at that same distance.



CLAUDIO CARIDI/DREAMSTIME.COM

13 WHAT IS THE *NEW GENERAL CATALOGUE*?

The *New General Catalogue of Nebulae and Clusters of Stars* is a list of deep-sky objects in order of right ascension. Compiled by Danish astronomer John Louis Emil Dreyer and published in 1888, the NGC contains 7,840 objects. A few of the many famous objects within it are NGC 2359 (Thor's Helmet), NGC 6822 (Barnard's Galaxy), and NGC 6543 (the Cat's Eye Nebula).

14 HOW MANY ACTIVE METEOR SHOWERS OCCUR EACH YEAR?

The American Meteor Society divides meteor showers into four classes. Class I showers are the major ones, such as the Perseids and Geminids. Nine of those happen annually. Then there are minor showers (Class II), variable showers (Class III), and weak showers (Class IV). These total at 18, 8, and 65, respectively, bringing the grand total to 100 annual showers.

15 HOW CLOSE IS THE NEAREST GALAXY TO EARTH?

If the Canis Major Dwarf Galaxy, discovered in 2003, turns out to be a true galaxy that is being torn apart by its interaction with the Milky Way, it is closest at 25,000 light-years away. If it isn't a galaxy, then the Sagittarius Dwarf Elliptical Galaxy, which lies some 78,000 light-years away, is closest.

16 HOW CAN YOU CALCULATE THE MAGNIFICATION OF AN EYEPIECE?



LUCHSCHEN/DREAMSTIME.COM

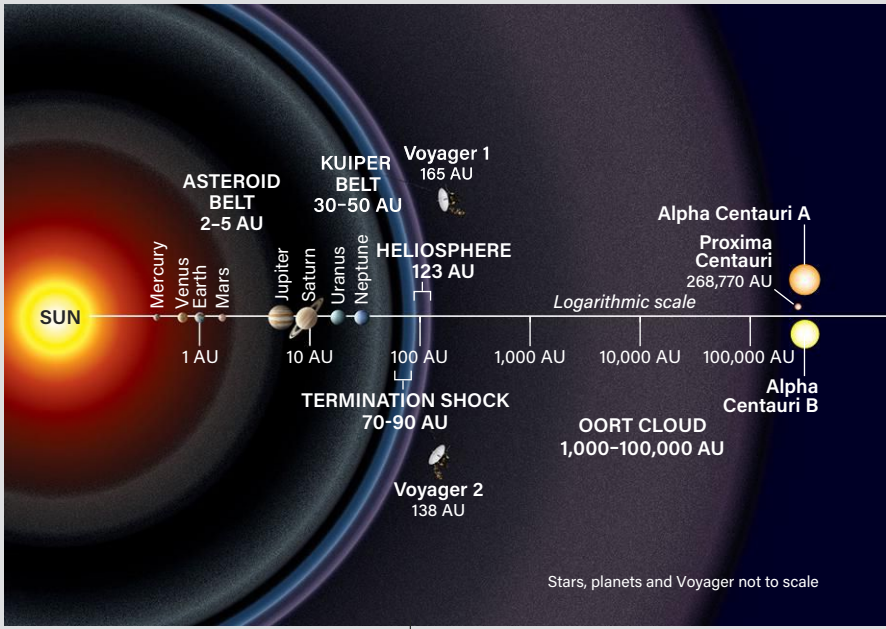
You'll need two numbers: the eyepiece's and telescope's focal lengths. All eyepieces have their focal length printed on them. When it comes to telescopes, it's often shown on the tube or on the ring around the front of the scope. If not, look in the owner's manual. To find the magnification, divide the focal length of the telescope by the focal length of the eyepiece. (Don't forget that they must be in the same units.)

17 WHAT WOULD A 150-POUND PERSON WEIGH ON THE MOON, MARS, AND JUPITER?

If your scale reads 150 pounds (68 kilograms) on Earth, it would say 24.9 pounds (11.3 kg) on the Moon and 56.5 pounds (25.6 kg) on Mars. Jupiter doesn't have a solid surface, but at its cloud tops, your weight would read 354 pounds (160.6 kg). (Note that your mass in kilograms would never actually change, but your scale is calibrated for Earth and would change its readout.)



DELSTUDIO/DREAMSTIME.COM



ASTRONOMY: ROEN KELLY

18 WHAT IS THE OORT CLOUD?

It's a sphere of perhaps trillions of planetesimals (small rocky or icy bodies) that surround the solar system. Dutch astronomer Jan Oort proposed the idea in 1950. The closest Oort Cloud bodies lie roughly 2,000 astronomical units (AU; 1 astronomical unit is equal to the average Earth-Sun distance of 93 million miles [150 million kilometers]) away. The farthest are 200,000 AU away, three-quarters of the way to the nearest star.

19 AFTER THE SUN, WHICH STAR LIES CLOSEST TO EARTH?

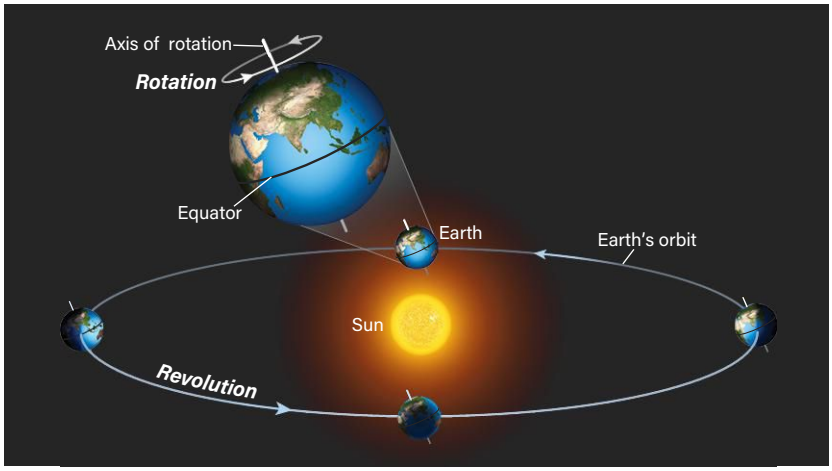
Most answers to this question are "Alpha Centauri." While correct in a general sense, Alpha — also known as Rigil Kentaurus — is a triple star. The two brightest components, Alpha Cen A and Alpha Cen B, lie 4.34 light-years away. Alpha Cen C (also called Proxima Centauri), however, is closer, at a distance of 4.24 light-years. Not much, you say? It's more than 265,000 AU!

20 HOW FAR FROM EARTH ARE THE TWO VOYAGER SPACECRAFT?

As of this writing, Voyagers 1 and 2 lie 15.37 billion miles (24.7 billion km) and 12.8 billion miles (20.6 billion km) away, respectively. You can see their current distances at http://science.nasa.gov/mission/voyager/where-are-they-now.

21 HOW FAR DOES OUR SOLAR SYSTEM EXTEND?

Astronomers define the edge of our solar system as the distance where the Sun's gravitational influence falls to zero. This is a bit farther than the Oort Cloud. (See question No. 18.) In 1964, Russian astronomer Gleb Alexandrovich Chebotarev calculated the edge of the solar system to be 230,000 AU from the Sun. If the Oort Cloud doesn't stretch as far as some researchers think, the extent of the solar system could be half of Chebotarev's estimate.



ASTRONOMY: ROEN KELLY

22 WHAT'S THE DIFFERENCE BETWEEN ROTATION AND REVOLUTION?

Rotation is the spinning of a body on an axis, like a twirling ballerina. Its axis is the imaginary line between the North and South poles. Earth rotates once a day. Revolution happens when one body orbits another, moving through space along a giant ellipse. Earth revolves around the Sun once a year.

23 WHO FIRST STATED THAT EARTH WAS ROUND AND NOT FLAT?

For many years, scholars thought that the Greek philosopher Pythagoras had come up with this concept. However, no evidence exists for that. The earliest reference we have for a round Earth comes from the *Phaedo*, a dialogue written between 388 B.C.E. and 367 B.C.E. by the Greek philosopher Plato.

24 HOW MUCH ENERGY DOES THE SUN EMIT IN ONE SECOND?

In the Sun's core, fusion is converting some 600 million tons of hydrogen into 596 million tons of helium every second. The remaining mass (less than one percent of the total) becomes energy. The result? Each second, the Sun is producing 383,000,000,000,000,000,000,000 kilowatts of power.

25 HOW MANY CRATERS ARE ON THE MOON?

Recent studies have identified more than 2 million craters on the Moon. Of these, 6,972 have diameters of 12.4 miles (20 km) or larger. It's estimated that 83,000 craters have diameters greater than 3.1 miles (5 km), and 1.3 million are 0.62 mile (1 km) or larger. However, the surface of our satellite contains only 9,137 craters that are officially recognized and named by the IAU.



VITALIJ KOPA/DREAMSTIME.COM

26 IS THERE WATER ON MARS?

Yes — however, all the surface water on the Red Planet is now frozen as ice. Mars' south polar ice cap alone contains enough ice to cover the planet in a sheet roughly 36 feet (11 meters) thick. Planetary scientists also think that some 4 billion years ago, Mars had a liquid ocean that may have covered one-third of the planet.



LEFT: ASTRONOMY: ROEN KELLY AFTER NASA

27 WHICH IS THE REDDEST NAKED-EYE STAR?

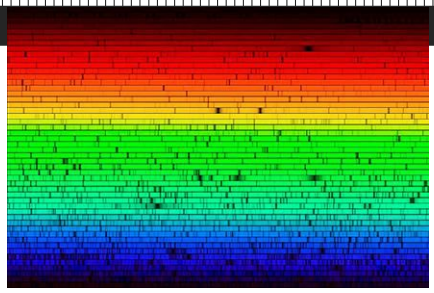
That would be carbon star V Hydrae, a variable star in the constellation Hydra. It normally hovers at 6th magnitude, but can drop to 12th magnitude at the faint end of a 17½-year cycle. If you look at it through a telescope, defocus the image slightly to make the color more apparent.

28 WHICH CONSTELLATION IS LARGEST?

Hydra the Water Snake is the largest constellation. It covers 1,302.84 square degrees, or 3.158 percent, of the sky. The next two largest star patterns are Virgo (1,294.43 square degrees/3.138 percent) and Ursa Major (1,279.66 square degrees/3.102 percent). This trio can be seen in the Northern Hemisphere's spring sky.



ALEXANDR YURTCHENKO/DREAMSTIME.COM



N.A. SHARP, NOAO/NSO/KITT PEAK FTS/AURA/NSF

29 HOW MANY CHEMICAL ELEMENTS ARE IN THE SUN?

Spectral analysis has identified 67 chemical elements in our daytime star. The two most abundant by far are hydrogen (91.2 percent of all atoms) and helium (8.7 percent). Rounding out the top 10 in abundance are oxygen, carbon, nitrogen, silicon, magnesium, neon, iron, and sulfur.

30 HOW MANY EXOPLANETS ARE THERE?

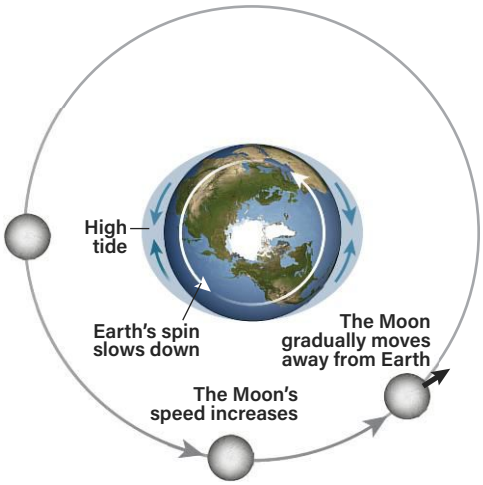
As of this writing, there are 5,765 confirmed exoplanets in the Milky Way Galaxy. For the latest statistics, see http://exoplanetarchive.ipac.caltech.edu/docs/counts_detail.html.

31 WHAT IS A BLACK HOLE?

This amazing object is the end product of the largest supernova explosions. (Note I'm talking here about stellar-mass black holes, different from supermassive black holes; see the next question.) As part of the explosion, the star's core collapses to a point where gravity overwhelms every other force. Nothing — not even light — can escape from a black hole.

32 WHAT IS A SUPERMASSIVE BLACK HOLE?

A supermassive black hole is one with a mass greater than 100,000 times that of the Sun. They reside in the centers of galaxies where the density of stars is high and where collisions cause objects to merge, although we don't know exactly how they form. Every large galaxy, including the Milky Way, contains a supermassive black hole.



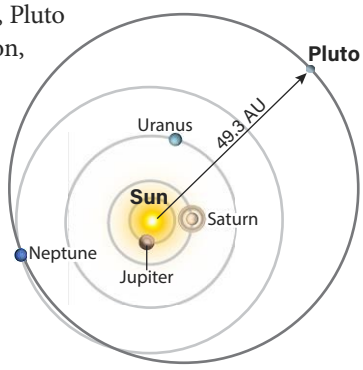
ABOVE: *ASTRONOMY*: ROEN KELLY

33 IS THE MOON MOVING AWAY FROM EARTH?

Yes, it is. The Moon's distance from us is increasing by 1.5 inches (3.8 centimeters) per year. Tides on Earth caused by the Moon are slowing our planet's rotation. As our planet's spin slows, the Moon's speed increases and it moves farther away, to keep the whole system balanced. And here's some trivia: Because of this increase, in approximately 600 million years, the Moon will appear so small that Earth will no longer experience total solar eclipses.

34 WHEN WILL PLUTO LIE FARTHEST FROM THE SUN?

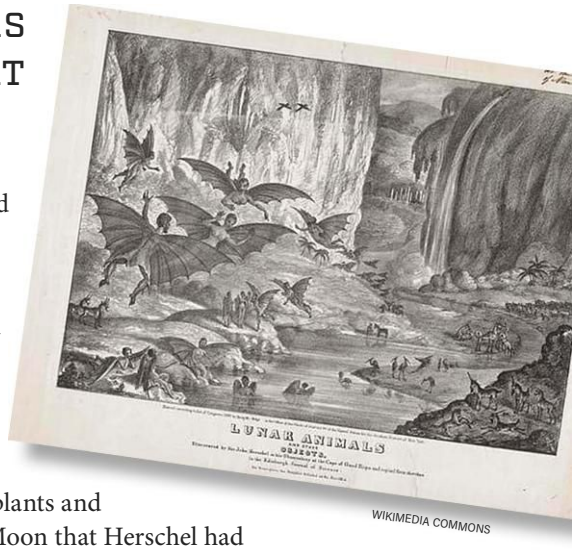
In February 2114, Pluto will reach aphelion, its farthest distance from the Sun. At that time, it will lie 49.3 AU away, which is 4.58 billion miles (7.38 billion km). Also at that time, Pluto will be traveling at its slowest orbital speed, approximately 8,280 mph (13,325 km/h).



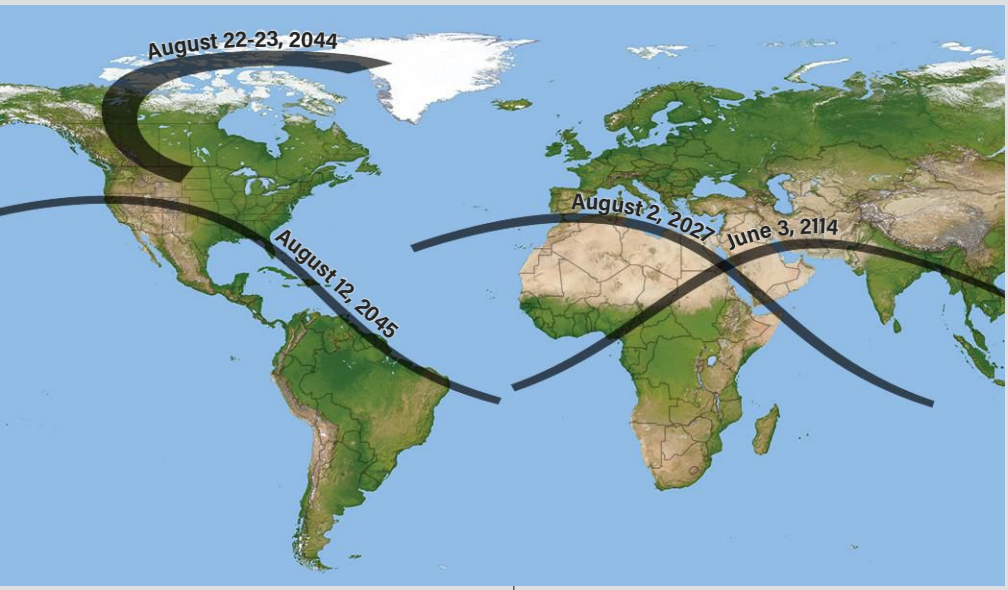
ASTRONOMY: ROEN KELLY

35 WHAT WAS THE GREAT MOON HOAX?

Beginning Aug. 25, 1835, *The Sun* (a newspaper based in New York City) ran a six-part series titled, "Great Astronomical Discoveries Lately Made by Sir John Herschel, L.L.D, F.R.S. &c. at the Cape of Good Hope." The articles, which were total fantasy, described various plants and animals that lived on the Moon that Herschel had "discovered" using the world's largest telescope, which purportedly had a lens 24 feet (7.3 m) in diameter!



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ASTRONOMY: ROEN KELLY

36 WHICH ECLIPSE IN OUR LIFETIMES HAS THE LONGEST TOTALITY?

The total solar eclipse on Aug. 2, 2027, will feature a maximum duration of totality of 6 minutes 23 seconds. That amount won't be bested until the eclipse on June 3, 2114, which features 6 minutes 32 seconds of totality.

37 WHEN IS THE NEXT GREAT AMERICAN ECLIPSE?

Although the continental U.S. will experience a total solar eclipse in 2044, it's of short duration and passes through only three states. The next Great American Eclipse will occur Aug. 12, 2045. It features a maximum of 6 minutes 6 seconds of totality and passes through 15 states, starting in California and ending in Florida.

38 WHICH NIGHTTIME STAR IS BRIGHTEST?

That's Sirius, sometimes called the Dog Star because it's the alpha star in the constellation Canis Major the Great Dog, visible in the Northern Hemisphere winter. It glows at magnitude –1.46, which is nearly twice as bright as the next brightest star.



VITALII IKOPA/DREAMSTIME.COM

39 WHY DO STARS EXPLODE?



Two processes can cause stars to explode. The most common, called a type II supernova, happens when a massive star uses up the nuclear fuel in its core. At this point, gravity overwhelms the outward force of radiation. The core then collapses and produces a massive amount of energy that blasts the star's outer layers into space. A different type of stellar explosion can occur when a white dwarf absorbs enough material from a companion star or collides with another star. When either happens, nuclear fusion begins again on the surface of the white dwarf and it blows itself apart. This is a type I supernova.

LEFT: ANTOINE GRELIN

40 HOW FAST DOES EARTH TRAVEL IN ITS ORBIT?

Our planet travels around the Sun in an elliptical orbit. It moves fastest when at perihelion (its closest point to the Sun, around Jan. 4) and slowest at aphelion (farthest from the Sun, around July 4). At perihelion, Earth's orbital speed is 67,750 mph (109,033 km/h), and at aphelion it's 65,500 mph (105,412 km/h). On average, we zoom around the Sun at 66,600 mph (107,182 km/h).

Michael E. Bakich *is associate editor of* Astronomy *who loves facts, both essential and trivial.*

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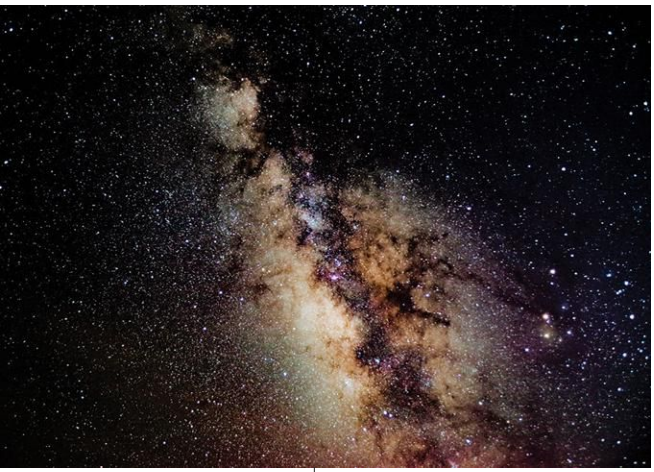






DSLR astrophotography

What can you do with just a camera and tripod?





When we think of astrophotography, usually big telescopes on robotic mounts that cost thousands of dollars come to mind. But you can capture beautiful astrophotos a different way — with only a camera and a tripod.

I created one of my first astrophotos on a work trip, on the side of the highway outside Albuquerque, New Mexico, with a lowly Nikon D3100, its kit 18-55mm lens, and a 6-inch tripod. I took nineteen 15-second images at ISO 6400 (and accidentally in JPEG!), stacked them using the beginner's stacking tool DeepSkyStacker, and got an exciting Milky Way shot that blew me away.

Time, practice, and use of the astrophotography software PixInsight have improved the quality of such images for me, but it's a good reminder of the incredible shots that can be captured without any tracking mount, telescope, or special camera. Be sure to capture images in the RAW format for the best quality. You can also try this with longer focal-length lenses (100mm or more, using shorter exposure times to prevent star trails), occasionally adjusting the tripod to keep the target centered, for smaller areas of the sky like the core of the Milky Way, the Orion Nebula (M42), or the field around the Andromeda Galaxy (M31).

Incredible images can be captured without any tracking mount, telescope, or special camera.

Under a dark sky, single-exposure nightscape images are another exciting way to capture what's overhead. A fast-focal-ratio lens (f/2.8 or lower) collects a lot of light, and some careful post-processing in Photoshop or PixInsight to increase contrast, reduce noise, and correct color can make a captivating astrophoto. Some cheaper lenses have a lot of chromatic aberration and coma when shot wide open, but one of my favorite affordable nightscape lenses with few of these issues is the Rokinon 14mm f/2.8. With some chromatic aberration correction in Photoshop, my even less-expensive Nikon NIKKOR 35mm f/1.8G has also delivered some fantastic shots.

Another type of image to create with just a DSLR and a tripod is a star-trail image. While they may appear as though the photographer just left the shutter open for a few hours, that actually would create an oversaturated image. Instead, using an intervalometer (which runs about $20 online), you capture 15- to 60-second exposures at somewhere between ISO 800 and 3200 for a few hours. These can be obtained in either JPEG or RAW. Then, using software such as the free Startrails application (startrails.de), you combine all the exposures to create a single image that shows the stars trailing across the sky. Having something interesting in the foreground can make a more compelling image, and facing the celestial pole showcases the wheel-like motion of the sky.

Focusing at night can be a challenge. One way to focus is to use a bright astronomical light, such as the Moon, Venus, or Jupiter, or even a distant streetlight. With a bright enough target, you can use the Live View camera function and digitally zoom in on the light, then adjust the focus manually (turn off autofocus!) until it's as sharp and small as possible. When such bright sources are absent, I usually take a three-second exposure, and then adjust the focus ring until the stars look pixelated — this is how you know you've reached focus. For fully manual lenses, the infinity focus mark on the lens is usually accurate. Lenses that have autofocus are a bit trickier to find infinity manually, but using short exposures and guess-and-check will get you there.

You don't need a fancy telescope or mount to get started in astrophotography! There's a lot you can do with just a DSLR and a tripod, even with inexpensive lenses. All you need is an intervalometer, a dark sky, and a sense of adventure!

LEFT TO RIGHT: The Milky Way from outside Albuquerque, New Mexico, glows without a telescope. The author shot nineteen 15s exposures at ISO-6400 on a tripod-mounted Nikon D3100 and 18-55mm lens at f/3.5.

Star trails mark the sky at Calhoun County Park in West Virginia. The author took 15-second exposures for a total of one hour and 23 minutes at ISO-3200, with a Nikon D5300 and a Rokinon 14mm lens at f/2.8.

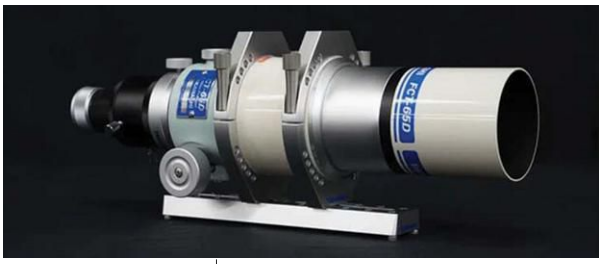
MOLLY WAKELING (2)



BY MOLLY WAKELING

Molly is an avid astrophotographer active in STEM outreach. She has a Ph.D. in nuclear engineering.

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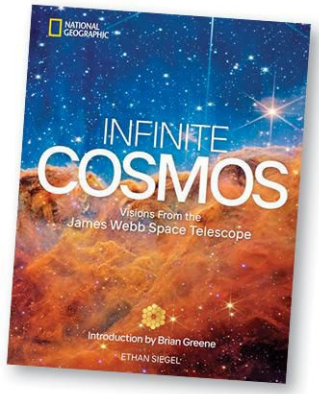
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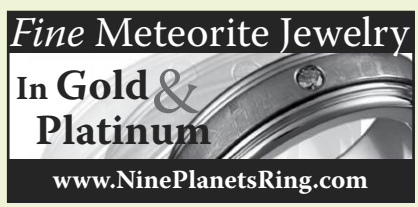
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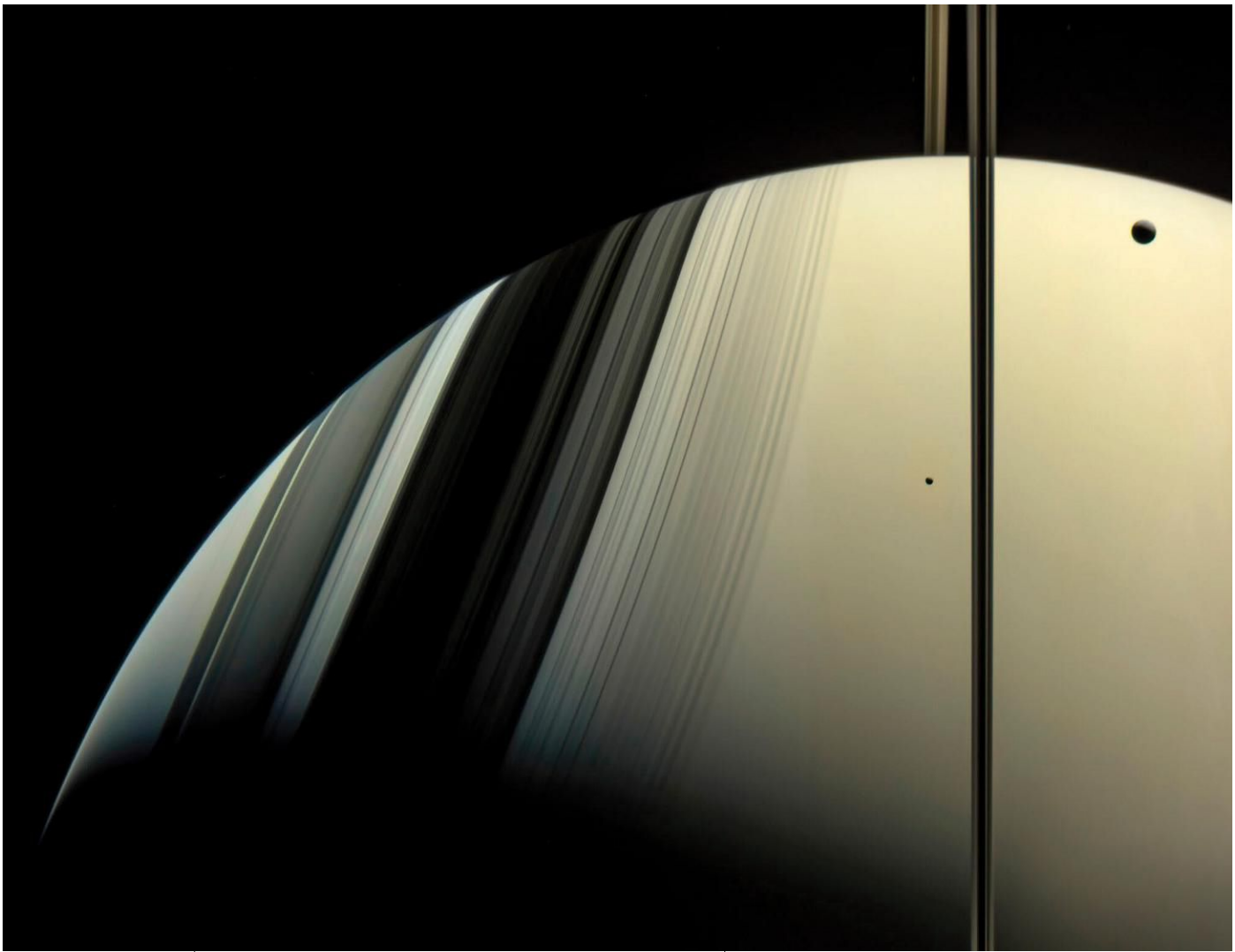


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This dramatic image of the ring shadows on Saturn was taken by Cassini July 16, 2005, when the rings were near their maximum tilt toward the Sun. The Sun is to the upper right. The thin vertical structure at right is the rings themselves. Two of Saturn's moons, Mimas and Tethys, are silhouetted against the planet.
NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE/JASON MAJOR

Ring shadows

Q WHY DON'T SATURN'S RINGS THROW A SHADOW ONTO THE PLANET'S SURFACE, LIKE ITS MOONS DO?

John Grimley
Toronto, Ontario

A The simple answer is that Saturn's rings *do* cast shadows on the planet's surface! NASA's Cassini spacecraft, which orbited Saturn from 2004 to 2017, took the dramatic image of the rings' shadows on Saturn shown above.

The major parts of Saturn's inner massive rings are visible in the lower image at right. The rings consist of huge numbers of mostly icy particles ranging from centimeters to many meters in size, plus dust and a few larger embedded moonlets. Their combined mass is similar to that of Saturn's moon Mimas. All these particles orbit Saturn in Saturn's equatorial plane. The particles do not emit visible light of their own but reflect and scatter sunlight. In some parts of the rings the particles are packed more densely than in others, which affects how bright they look because of scattered light and how dark their shadows are. In the same image at right, the more densely packed parts of the rings, like the A and B rings, are brighter because they backscatter more sunlight, while the Cassini division and the C Ring are dimmer. (There are a few dark gaps where there is little material.)

For an Earth-based observer, however, the ring shadows can be difficult to notice for two reasons. First, the

rings themselves can get in the way of seeing the shadows from our perspective. Second, at times when we do get a glimpse of the shadows, one needs a decent telescope and good seeing to notice them.

Saturn is 10 times farther from the Sun than Earth. So, as seen from Saturn, Earth is always nearly in the same direction as the Sun, within about 6°. As a result, the bright face of the rings gets in the way of seeing the ring shadows from Earth.

NASA'S CASSINI SPACECRAFT TOOK MANY DRAMATIC IMAGES OF THE RINGS' SHADOWS ON SATURN.

Saturn's rotation axis is tilted with respect to its orbital plane around the Sun by about 26.7° — not too different from Earth's 23.5°. Like a spinning top, the orientation of Saturn's axis and the equatorial rings remain relatively fixed in space. So, twice per orbit, the rings are edge-on to the Sun and produce only a slender shadow across Saturn's equator. Between these edge-on events, for about half the orbit, the northern face of the rings tilts toward the Sun, casting shadows on Saturn's southern hemisphere; for the other half, the southern ring face is toward the Sun and shadows are cast on Saturn's northern hemisphere. The extent of the ring shadows on the planet varies quite a bit depending on the tilt of the rings relative to the Sun.

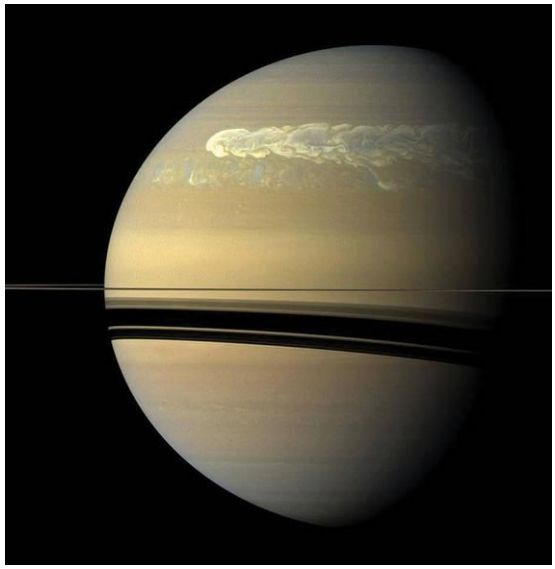
At times near maximum tilt of the rings to the Sun, the shadows produced by the rings cover a large part of the daylight side of Saturn, as shown in the image at left — but at those times, the bright face of the rings hides the extensive shadows for an observer on Earth.

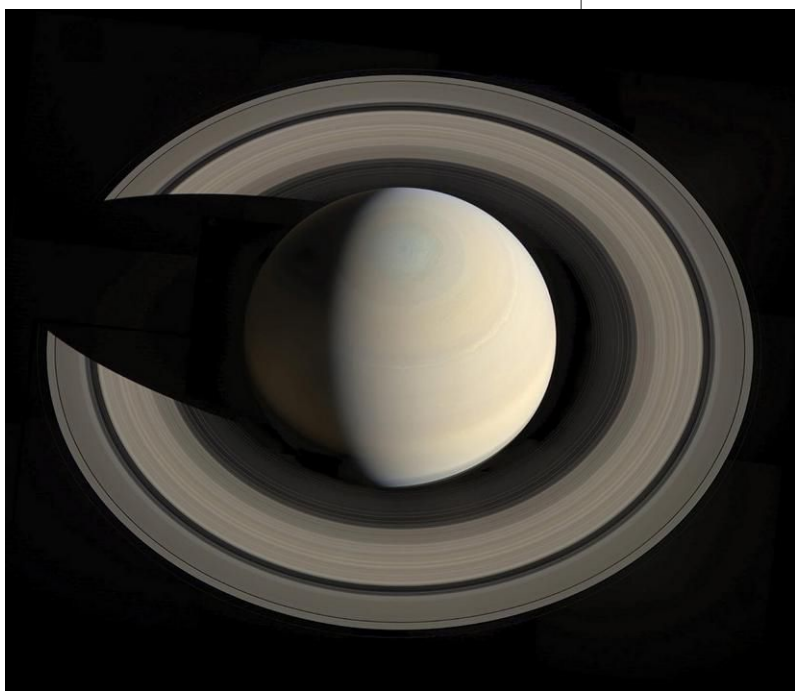
The spectacular Cassini image at left was taken just a few years after the maximum opening of the rings to the Sun that occurred in 2002 (seen from Earth, this maximum happens roughly every 15 years). Using gravitational assists from Saturn's moons, Cassini regularly changed its orbit around Saturn, resulting in a wide variety of perspectives on the ring shadows, as illustrated by many images you can find from the mission, such as those at left and right.

The second reason, seeing, refers to how much small fluctuations in Earth's atmosphere blur our view of astronomical objects. "Good" seeing refers to when these fluctuations are relatively mild, but good seeing is almost as hard to find these days as views free of light pollution. That's one reason professional optical telescopes are on mountaintops or placed in orbit or on interplanetary spacecraft like Cassini.

So even an observer on Earth with a decent telescope can have a hard time actually seeing the rings' shadows. Let's quantify that. Really good seeing, which is again hard to come by, will blur a star by one second of arc (1") in angle. Saturn is only 15" to 20" in diameter as seen from Earth. And the glimpses we get of the ring shadows from Earth during times of minimum ring tilt can be thinner than an arcsecond. (See "A Saturn ring mirage" in the November 2024 issue for more details about making such a challenging observation.)

Richard H. Durisen and Paul R. Estrada
Professor Emeritus of Astronomy, Indiana University, Bloomington, Indiana, and Research Scientist, NASA Ames Research Center, Mountain View, California





LEFT: A Cassini image captured Feb. 25, 2011, shows the rings nearly edge-on as the narrow line cutting horizontally across Saturn's equator. The Sun is to the left. A large storm at high latitude is overtaking itself as it circles the planet. NASA/JPL-CALTECH/SSI

BELOW: This visible light image shows Saturn and its main rings. The outermost bright band is the A Ring. The Cassini Division separates the A Ring from the brightest broad band, called the B Ring. The C Ring is the sparser grayish ring inside the B Ring. Notice that in visible light, the rings only reflect and scatter sunlight, so they are dark where they enter Saturn's shadow on the left. NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE/G. UGARKOVIC



This artist's conception shows the view from Earth some 3.75 billion years from now, as Andromeda (at left) appears much larger in our sky, while the plane of the Milky Way (at right) has started to become distorted by its approach. NASA; ESA; Z. LEVAY AND R. VAN DER MAREL, STSCI; T. HALLAS; AND A. MELLINGER

Q | IF EVERYTHING IN OUR SOLAR SYSTEM FORMED FROM THE SAME SOLAR NEBULA, WHY DO THE PLANETS HAVE DIFFERENT COMPOSITIONS?

Herbert Wich
Titusville, Florida

A | To better understand why the planets have variable compositions, we have to first understand the process of how stars form. While the composition of gas and dust in a precursor molecular cloud is fairly uniform before star formation, everything changes once a cloud core begins to gravitationally collapse.

The collapse of a cloud core can be triggered by many factors. One theory is that our Sun's formation was initiated by a nearby supernova explosion. During this collapse, the central gas and dust became more and more dense, and the surrounding gas flattened into a disk as it spun with the angular momentum of the system. The temperature of the central core rose as it became increasingly dense and opaque, and eventually became hot and dense enough that nuclear fusion began. The proto-Sun was ignited.

During the early life of a protostar, the dust in the surrounding disk remains cool. But once the star ignites, the inner layers of dust heat up dramatically. As our Sun grew, the disk structure evolved with decreasing density and temperature gradients moving radially outward away from the proto-Sun, and with increasing density toward the midplane of the disk. This heterogeneity is ultimately what led to differences in the planets' compositions. Elements and molecules that are volatile (meaning they require colder temperatures to solidify or condense) remained as gas close to the Sun where it was hot, while only the less-volatile elements such as calcium, aluminum, iron, and silicon could solidify into dust and rocky debris. These rocky bits eventually coalesced to form the terrestrial planets.

However, at a distance of around 4 astronomical units from the Sun (AU; 1 AU is the average Sun-Earth distance of 93 million miles [150 million kilometers]), the temperature in the disk was cold enough for water vapor to freeze into solid ice, at what is called the snow line. Past this distance, the protoplanets rapidly accreted large volumes of water ice and other volatiles such as ammonia and methane in addition to dust and rock. They quickly became massive enough to also gravitationally trap gases such as hydrogen and helium from the disk. This runaway growth led to the formation of the gas and ice giants in the outer solar system.

This first-order model of planetary growth in the solar nebula is mainly driven by temperature and density variation, but there are many other factors that contributed as well, such as planet migration, material transport, collisions, and outgassing. Furthermore, many open questions remain about the early stages of

planet formation — we aren't even certain of the origin of water on Earth — but scientists continually discover and debate exciting theories that improve our understanding.

Christie Jilly
Research Scientist and Lab Manager, Department of Earth & Planetary Sciences, Stanford University, Stanford, California

Q | WHAT WILL HAPPEN TO THE SOLAR SYSTEM WHEN THE MILKY WAY COMPLETES THE MERGER WITH THE ANDROMEDA GALAXY?

Bryan Mitchell
Maricopa, Arizona

A | Your excellent question affords us the opportunity to distinguish between near-certain astronomical predictions and those which are far less so.

Astronomers predict that our home galaxy and the nearest major galaxy to it, Andromeda (2.5 million light-years away), will collide and eventually merge between 3.9 billion and 5.6 billion years from now. They've been fairly certain about this since 2012, when researchers precisely measured the motions of many stars within the Andromeda Galaxy and found that these stars were approaching the Milky Way. Presently, the two galaxies are moving toward each other at 250,000 mph (402,300 km/h), so that in the time required for you to read this sentence, the separation between Andromeda and the Milky Way will have diminished by nearly 800 miles (1,300 km).

Astronomers also know that these two galaxies will not merely crash together. Instead, they'll undergo a series of encounters. According to a recent model, the first merger will occur about 3.9 billion years from now. The galaxies will then separate, slow down, and move back toward each other before colliding again in 5.1 billion years. The subsequent separation will be briefer, because their gravity will prevent them from straying too far apart. In about 5.4 billion years, the two galaxies will finally merge into a galaxy of more than 1 trillion stars.

So what will all this galactic motion do to the solar system? Honestly, we can't provide an answer with any certainty. The most educated guess so far comes from T.J. Cox and Avi Loeb of the Harvard-Smithsonian Center for Astrophysics. They published a paper in the May 2008 issue of *Monthly Notices of the Royal Astronomical Society* entitled "The Collision Between the Milky Way and Andromeda." (Admittedly, be wary of the term "collision." Even a galaxy containing billions of stars is mostly empty space. To quote a December 2023 Astronomy.com article, "if the Sun were a ping-pong ball, then Proxima Centauri [the closest star to the Sun] would be a pea about 680 miles [1,100 km] away.")

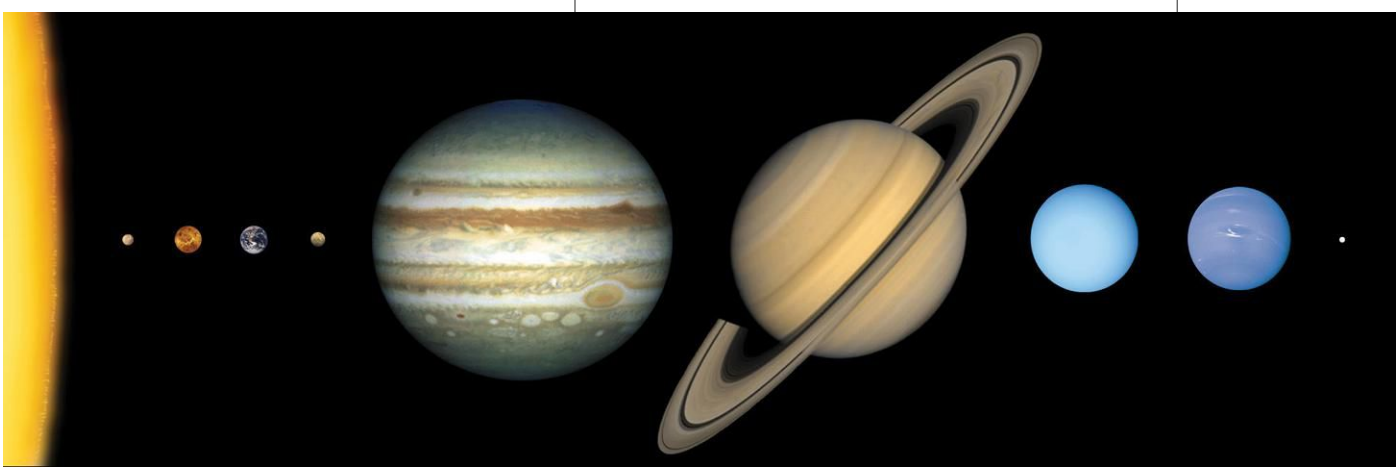
In that paper, they predict a 50 percent chance that our solar system will be pushed away from the galactic core by three times its current distance of 26,660 light-years. That displacement would propel the solar system toward the outer edge of the newly formed supergalaxy. Cox and Loeb also calculate that there is a 12 percent chance that the turbulent collisions will eject the solar system into the vast gulf of intergalactic space.

As for the solar system itself, stellar models assure us that the Sun will still be a main sequence star during these mergers, although it will be reaching the end of its core-hydrogen-burning phase. There will be no life on Earth at this time — increasing solar luminosity will have eradicated all life about 2.8 billion years before the first Milky Way/Andromeda close encounter. However, if this were not true, and provided that Earth wasn't dislodged from the solar system itself, even the solar system's ejection into intergalactic space wouldn't imperil life on this planet. Remember, we rely on only one star: the Sun. Being propelled away from the other stars, though not an ideal situation from an astronomer's point of view, would cause us little harm. Based on the distance to Proxima Centauri (4.2 light-years), the Sun and its attendant bodies are isolated within a sphere of some 310 cubic light-years. So, we're quite displaced from the other stars already and we're still alive and well.

Edward Herrick-Gleason
Astronomy Educator, St. John's, Newfoundland and Labrador

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Send your astronomy questions via email to **askastro@astronomy.com**. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

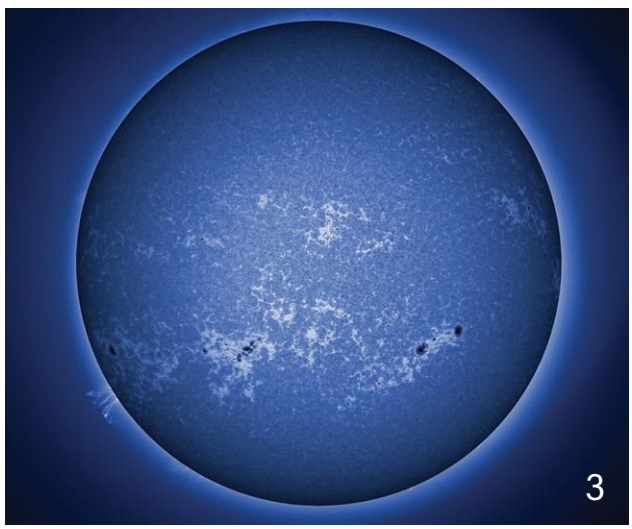


The Sun and planets of our solar system all formed from the same cloud of gas and dust, but the planets' compositions vary with mass and distance from our star. This illustration shows the planets' (and Pluto's) relative sizes to scale, but not their relative distances from the Sun. NASA/LUNAR AND PLANETARY INSTITUTE









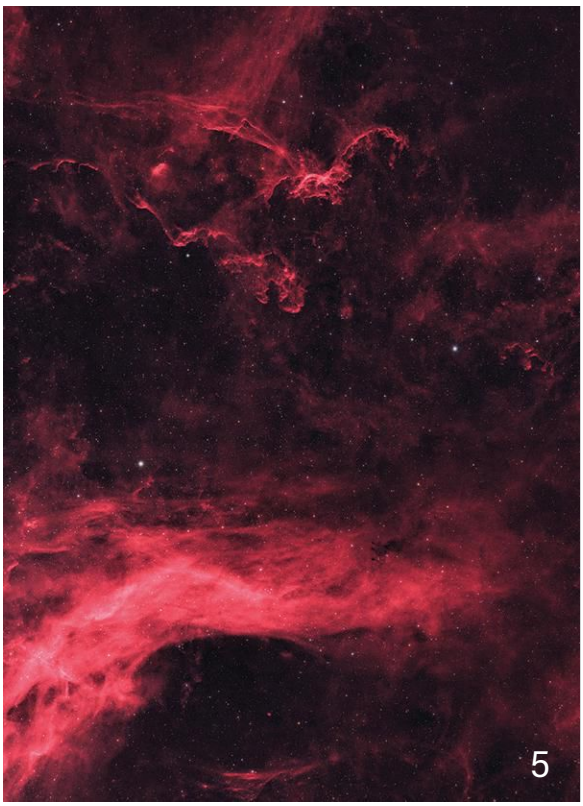


1. EYE OF THE UNIVERSE
The Helix Nebula (NGC 7293) is a planetary nebula roughly 650 light-years away in Aquarius, the result of a dying star sloughing off its outer layers as it runs out of fuel. This photo represents 342.5 hours of exposure collected by 19 amateur astroimagers with telescopes ranging from 2.8 inches to 12 inches in aperture. The extreme amount of data reveals extensive detail in the outer ionized hydrogen shells. ***• Overall Photons: Andrea Iorio/Elisa Cuccu/Fernando Linsalata/Javier Caldera/Paul Montague/Carlos Uriarte Castillo/Darius Kopriva/Drew Evans/Bruno Rota Sargi/Blake Behrends/Manuel Alejandro Chavarría Silva/Phillip Hoppes/Jan Beranek/Roberto Volpini/Pier Mattia Basciano/Marco Finatti/Jeff Ratino/Vakhtang Khutsishvili/Patrice Soom***

2. UNDER THE TUSCAN SUNS
The stars pirouette around Polaris above the hills of Tuscany near Pisa, Italy, in this two-panel panorama taken with a Nikon Z9 mirrorless camera and 70mm zoom lens. The sky was captured with 170 exposures of 15 seconds at f/4.5 and ISO 250. ***• Marco Meniero***

3. CALCIUM ARCADE
A magnificent arcade of coronal loops appeared on the Sun's limb Sept. 1, 2024, captured here with a 3.2-inch refractor, CMOS camera, and a Calcium-K filter. These arcing features are caused by glowing plasma trapped in the Sun's magnetic field. While often seen in Hα, they are less frequently visible in the Sun's fainter CaK emission. ***• Chris Schur***

4. REACHING ACROSS THE SKY
The Sailboat Cluster (NGC 225) glides through Cassiopeia, roughly 2,300 light-years away. The azure reflection nebula beneath it is van den Bergh 4 and the dark nebula to the lower right is LDN 1291. ***• Bob Fera/Steve Mandel***





5. THE GREAT RED DRAGON
The Flying Dragon Nebula (Sharpless 2–114) in Cygnus is a faint emission nebula that glows almost entirely in Hα, with little emission in OIII or SII. This image comprises 18.5 hours of Hα data with a 2.8-inch f/6 scope. ▪ ***David Joyce***

6. COSMIC CONFLUENCE
The crowded core of the Milky Way (at top) and the colorful Rho Ophiuchi cloud complex (at right) hang over the Drang-Drung Glacier in India's Ladakh region. The imager captured the sky with a Sony mirrorless camera and a 50mm lens, taking two-minute subframes at f/3.5 and ISO 2500 for a total of 60 minutes of exposure. ▪ ***Anushtup Roychoudhury***

7. A METEORIC VOLLEY
Perseid meteors streak above Xiaochaidan Lake in China's Qinghai Province in this 17-panel panorama of 60-second subframes taken with a Nikon DSLR and a 14mm lens at f/1.8. Sky frames were captured at ISO 2000 and the foreground at ISO 800. ▪ ***Xiaofeng Qu***



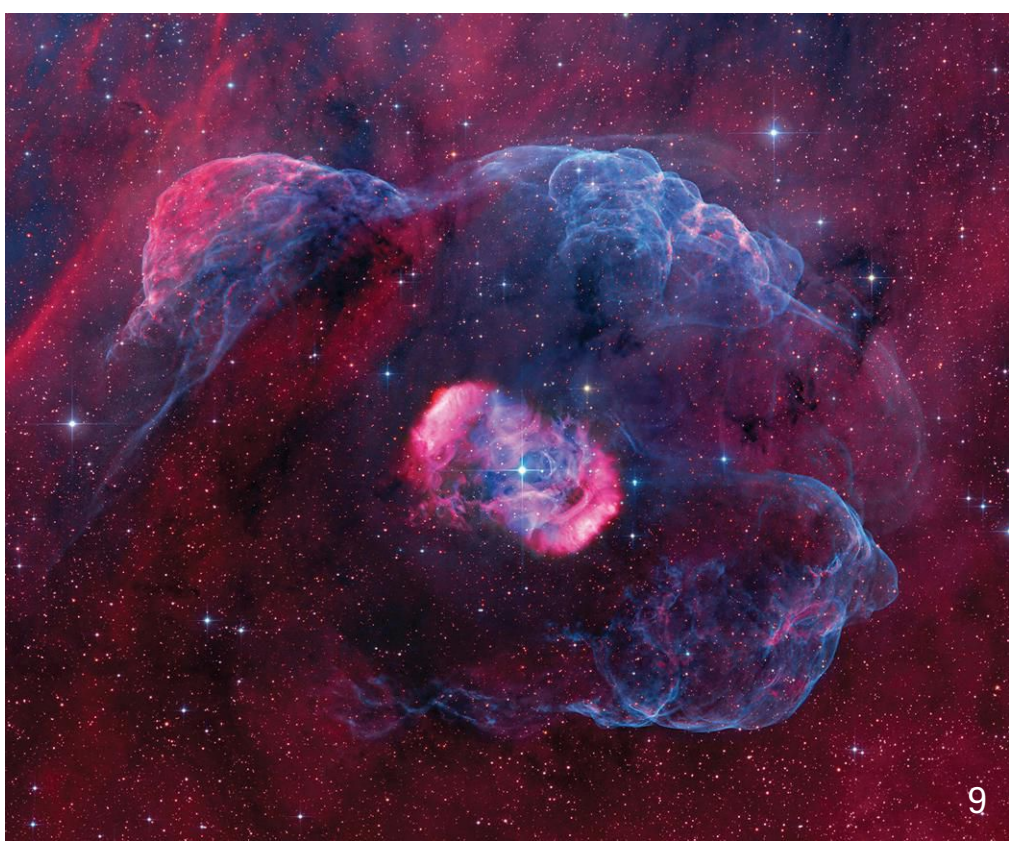


8. BENT OUT OF SHAPE
Spiral galaxy NGC 1532 lies 50 million light-years away in Eridanus. Its dwarf galaxy companion NGC 1531 has bent one of the main galaxy's arms out of shape as it makes a close pass. This LRGB image comprises 15.5 hours of exposure with a 5-inch refractor. ▪ ***Charles Pevsner***

9. DRACONIC FRATRICIDE
At a distance of 3,900 light-years, in Norma the Square, lies NGC 6164/5, also known as the Dragon's Egg. Astronomers think the binary star at its center, HD 148937, was originally a triple system. The billowing outer shell was caused by stellar winds early in the system's life; the inner nebulae was created when two of the three stars merged a few thousand years ago, a 2024 study found. The imager used a 24-inch scope to take 5.5 hours of exposure through Hα/OIII/LRGB filters. ▪ ***Kfir Simon***

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Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures.







SO CLOSE, AND YET SO FAR

Appearances can be deceiving — particularly when looking at a two-dimensional image of the 3D cosmos. The bright galaxy NGC 1356 dominates the right side of this image. A 13th-magnitude barred spiral, NGC 1356 dwells among the foreground stars of the southern constellation Horologium the Clock. Although it seems to be interacting with the smaller spiral LEDA 95415 immediately to its left, that's just an illusion. The expansion of the universe allows astronomers to calculate the third dimension of distance, revealing NGC 1356 to be 550 million light-years from Earth while LEDA 95415 lies 840 million light-years away. The face-on spiral on the image's left side, IC 1947, resides 500 million light-years from Earth, so it's much closer to NGC 1356 than LEDA 95415 is. ESA/HUBBLE & NASA, J. DALCANTON, DARK ENERGY SURVEY/DOE/FNAL/NOIRLAB/NSF/AURA

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April 2025
Venus blazes at dawn

Face north after darkness falls and the prominent constellations Taurus, Orion, Canis Major, and Gemini will grab your attention. **Mars** resides in the last of these star groups during April's first half. The magnitude 0.4 planet starts the month 4° south of Gemini's luminary, 1st-magnitude Pollux. Mars' eastward motion relative to the background stars carries it into Cancer on the 13th, and it ends the month shining at magnitude 0.9 near the center of the Crab.

Unfortunately, the ruddy world won't look like much even through a large telescope. Its apparent diameter shrinks from 8.2" to 6.6" during April, too small to show much detail except during moments of exceptional seeing.

Although Mars remains prominent, it doesn't hold a candle to brilliant **Jupiter**. The giant planet shines at magnitude –2.0 against the backdrop of Taurus the Bull, which lies lower in the northwest as night falls.

A telescope reveals Jupiter's 35"-diameter disk highlighted by two dark atmospheric belts that run parallel to the gas giant's equator. The planet's low altitude likely precludes seeing much further detail. Any scope also shows Jupiter's four bright Galilean moons.

Once Mars sets around midnight local time, the sky remains clear of naked-eye planets until the approach of dawn. That's when Mercury, Venus, and Saturn push above the eastern horizon. The trio rises about an hour before sunup in early April and two to three hours before the Sun at month's end. The three form a lovely triangle for early risers.

Venus dominates the scene. The inner world peaks at magnitude –4.8 in late April, shining some 100 times brighter than Mercury. Venus is pulling away from the Sun following its inferior conjunction in late March and grows even more dazzling as it climbs higher in a dark sky.

This is the time to observe Venus through a telescope. The planet's apparent size and phase change noticeably from week to week. On April 1, Venus shows a disk 57" in diameter that's just 4 percent lit. As the month closes, the planet spans 37" and the Sun illuminates 28 percent of its Earth-facing hemisphere.

Like Venus, **Mercury** passed through inferior conjunction in late March and grows increasingly prominent during April. The innermost planet reaches greatest elongation April 21, when it lies 27° west of the Sun and stands 14° above the eastern horizon an hour before sunrise. Mercury brightens slowly this month, achieving magnitude 0.1 by month's end.

The planet's telescopic appearance changes even more rapidly than Venus' does. The beginning of April finds Mercury sporting an 11"-diameter disk that's 7 percent lit. By month's end, it appears 7" across and 58 percent lit.

Saturn glows at magnitude 1.2 on the border between Aquarius and Pisces. Despite its low altitude, the planet offers a rare treat for telescope owners this month — the opportunity to see its glorious rings backlit. While Earth passed through Saturn's ring plane in late March, the Sun doesn't cross until early May. The best views should come late in the month once Saturn climbs higher in the predawn sky.

The starry sky

Although I have never seen a bird of paradise, I certainly hope to one day. Photographs show a magnificent if unusual creature, with males displaying long and elaborate feathers.

This makes viewing the constellation Apus, which represents the lovely bird, rather disappointing. Most egregiously, the bird's tail feathers have been downsized. On April evenings, you can find Apus at the same altitude and to the left of the South Celestial Pole. The constellations Chamaeleon, Musca, Circinus, Triangulum Australe, Ara, Pavo, and Octans border Apus.

In February, I wrote about a group of four stars in Octans near the South Celestial Pole. This month, I want to highlight a different set of four, though close inspection reveals it to be a group of five because one turns out to be a naked-eye pair. The set comprises Delta (δ), Rho (ρ), Omega (ω), and Pi^1 (π^1) and Pi^2 (π^2) (the naked-eye pair) Octantis.

These four lie close to the border with Apus, centered at a declination of about –85° and roughly halfway between the pole and 4th-magnitude Alpha (α) Apodis. In Johann Bayer's 1603 masterpiece, *Uranometria*, he included this group as part of the bird's magnificent tail feathers. The book showed the tail spread out from the feet of the Chamaeleon (Beta [β], Delta^1, and Delta^2 Chamaeleontis) almost to the pole, but things had changed by the mid-18th century. Octans was now there, and Apus' tail had to make way for part of the navigational instrument.

On Johann Bode's *Uranographia* in the early 19th century, the tail feathers appear less than half as wide as before and actually narrower than the main part of the bird's body.

In the early days after the introduction of Apus, the sky was less crowded. The lovely bird had room to spread its feathers before 18th-century French astronomer Nicolas Louis de Lacaille introduced 14 new constellations, of which Octans was one. Thus, the stars that proudly marked the middle of Apus' tail feathers in 1603 are now officially part of Octans.

The lack of bright stars in this area makes it a joy to scan with binoculars. I particularly enjoy the view of the delicate pairing of Pi^1 and Pi^2 Oct.

STAR DOME

HOW TO USE THIS MAP

This map portrays the sky as seen near 30° south latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

9 P.M. April 1
8 P.M. April 15
7 P.M. April 30

Planets are shown at midmonth

MAP SYMBOLS

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

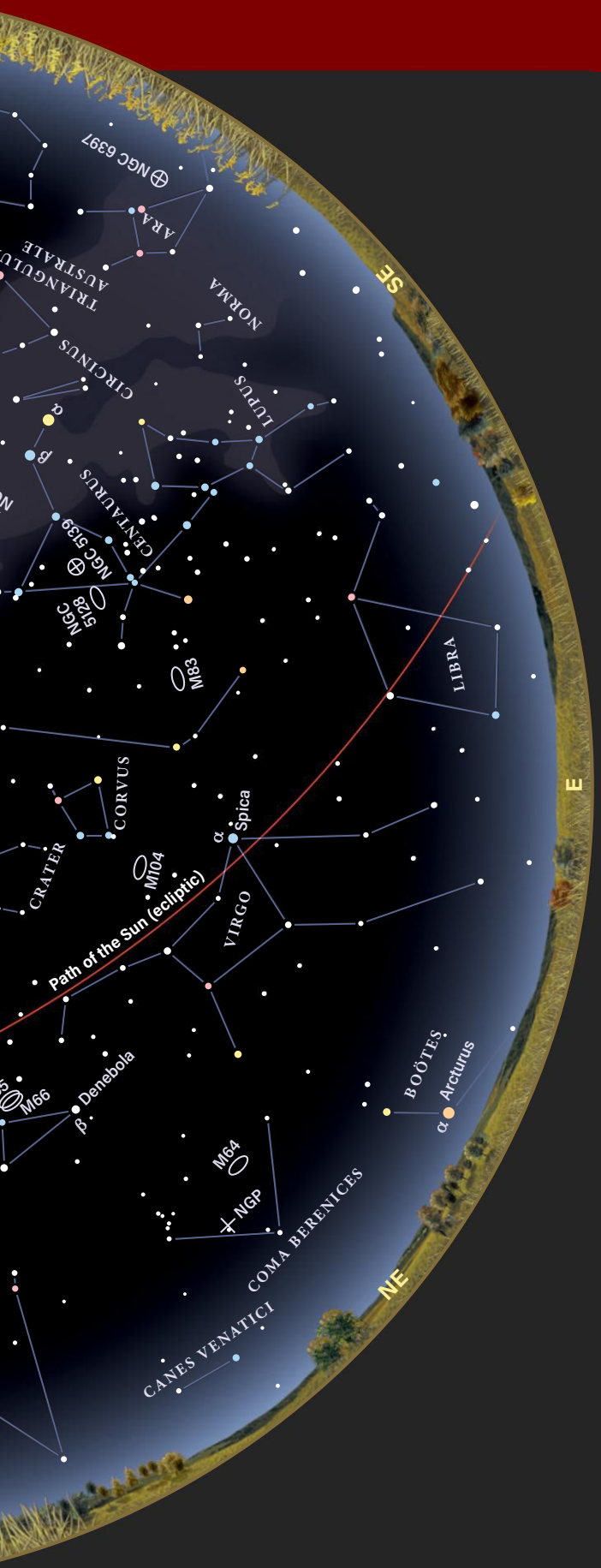
STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



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SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

CALENDAR OF EVENTS

1 The Moon passes 5° north of Uranus, 14h UT

3 The Moon passes 6° north of Jupiter, 0h UT

Mars passes 4° south of Pollux, 3h UT

5 First Quarter Moon occurs at 2h15m UT

The Moon passes 2° north of Mars, 19h UT

6 Mercury is stationary, 6h UT

10 Venus is stationary, 15h UT

13 Full Moon occurs at 0h22m UT

The Moon passes 0.3° south of Spica, 2h UT

The Moon is at apogee (406,295 kilometers from Earth), 22h48m UT

16 Mercury passes 0.7° south of Neptune, 19h UT

Mars is at aphelion (249.2 million kilometers from the Sun), 22h UT

The Moon passes 0.4° south of Antares, 23h UT

21 Last Quarter Moon occurs at 1h36m UT

The Moon passes 0.7° south of Pluto, 6h UT

Mercury is at greatest western elongation (27°), 19h UT

22 Lyrid meteor shower peaks

25 The Moon passes 2° south of Venus, 1h UT

The Moon passes 2° north of Saturn, 4h UT

The Moon passes 1.9° north of Neptune, 10h UT

26 The Moon passes 4° north of Mercury, 1h UT

27 Venus is at greatest brilliancy (magnitude –4.8), 10h UT

The Moon is at perigee (357,119 kilometers from Earth), 16h18m UT

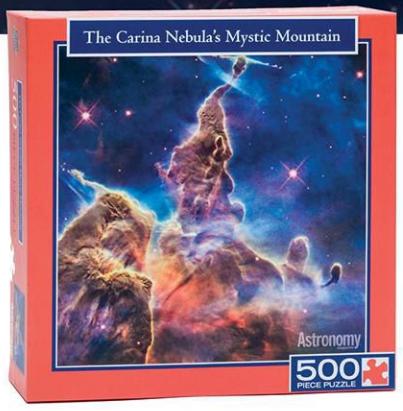
New Moon occurs at 19h31m UT

29 The Moon passes 5° north of Uranus, 2h UT

Venus passes 4° north of Saturn, 2h UT

30 The Moon passes 5° north of Jupiter, 18h UT

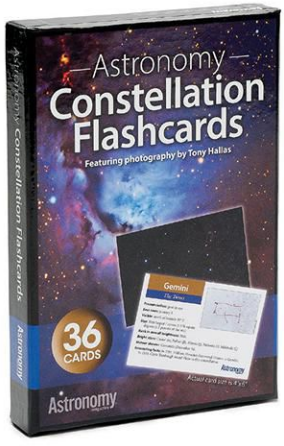
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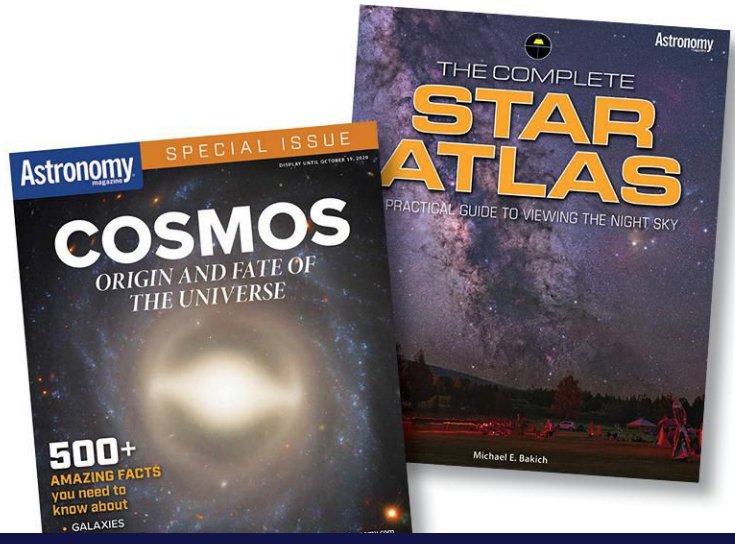
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